UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 949

Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C. ▼ October 10, 1921

STANDARD AND TENTATIVE METHODS OF SAMPLING AND TESTING HIGHWAY MATERIALS

Recommended by the

SECOND CONFERENCE OF STATE HIGHWAY TESTING ENGINEERS AND CHEMISTS

Washington, D. C., February 23 to 27, 1920

CONTENTS

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CONTENTS.

INTRODUCTION.

In connection with the administration of Federal appropriations for highway construction, conferences have been held from time to time, between representatives of the Bureau of Public Roads and of the various State highway departments, for the purpose of formulating policies relative to matters of mutual interest. In accordance with this general plan, a conference of testing engineers of the State highway departments was deemed advisable in order to standardize the work of the State highway department laboratories and the bureau laboratories.

The conference held at the Bureau of Public Roads, Washington, was called by the committee on tests and investigations of the American Association of State Highway Officials and the following representatives of State highway departments and of the Bureau of Public Roads were in attendance, for all or a part of the conference:

Agg, T. R., Iowa.
Anderton, B. A., Bureau of Public Roads.
Begg, R. B. H., Virginia.
Bragg, J. G., New Jersey.
Carmick, L. G., Bureau of Public Roads.
Cooper, W. F., Louisiana.
Dayton, R. B., West Virginia.
Dean, A. W., Massachusetts.
Gage, R. B., New Jersey.
Goldbeck, A. T., Bureau of Public Roads.

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Grimes, J. F., Kentucky.
Hinderlite, H. B., North Carolina.
Hutchinson, G. W., Delaware.
Jackson, F. H., Bureau of Public Roads.
Lang, F. C., Minnesota.
Leavitt, H. Walter, Maine.
Maddocks, Frederick T., California.
Martin, W. D., Ohio.
Milburn, Henry M., Bureau of Public Roads.
Purrington, W. F., New Hampshire.
Rea, A. S., Ohio.
Roman, F. L., Illinois.
Rossell, F. C., Maryland.
Saunders, R. L., Connecticut.
Seaton, R. A., Kansas.
Smith, E. B., Bureau of Public Roads.
Terrell, D. V., Kentucky.
Ulman, Malcolm H., Pennsylvania.
Withey, M. O., Wisconsin.

The important recommendations which resulted from the conference are due largely to the painstaking and effective work of the testing engineers who participated.

Standard methods of sampling and testing the materials employed in highway construction were adopted, as set forth in this bulletin. It will be noted that the standard methods adopted by the American Society for Testing Materials have been accepted so far as the field has been covered by that society. In some of the methods minor revisions of the A. S. T. M. standards have been made, and where that has been done, the notation that follows the title of the test or method indicates that there has been such revision.

For tests that have not been standardized by the American Society for Testing Materials, the methods of testing set forth in Bulletins 314, 347, and 555 of the U. S. Department of Agriculture, contributed by the Bureau of Public Roads, have been adopted for the most part. Several new tests and revisions of old tests are suggested for trial, to be adopted later if they prove to be satisfactory.

It will be noted that for the convenience of testing departments, there is given the full text of all tests usually employed in a highway department testing laboratory. This has been done because it is believed it will save time and avoid confusion to have all of this material available in a single volume.

The tests set forth in this bulletin are recommended as official standards by the committee on tests and investigations of the American Association of State Highway Officials, and this recommendation is concurred in by the Bureau of Public Roads.

The recommendations of the conference were assembled and arranged by T. R. Agg, chairman of the committee on tests and investigations of the American Association of State Highway Officials, and A. T. Goldbeck, engineer of tests of the Bureau of Public Roads.

TESTS FOR NON-BITUMINOUS ROAD MATERIALS.

1. ABRASION TEST FOR BROKEN STONE.

(A. S. T. M. Standard method, serial designation D 2–08, slightly modified.)

(1) The machine (see fig. 1) shall consist of one or more hollow iron cylinders, closed at one end and furnished with a tightly fitting iron cover at the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth inside. These cylinders are to be mounted on a shaft at an angle of 30° with the axis of rotation of the shaft.

(2) The rock to be tested shall be broken from large irregular pieces to as nearly uniform size as possible, and as near to 50 pieces as possible shall constitute a test sample. No pieces having edges or faces that have been rounded by wear shall be included. The total weight of rock in a test shall be within 10 grams of 5 kilograms. All test pieces shall be washed and thoroughly dried before weighing. Ten thousand revolutions, at the rate of between 30 and 33 per minute, shall constitute a test. Only the percentage of material worn off which will pass through a 0.16-cm. ($\frac{1}{16}$-inch) mesh sieve shall be considered in determining the amount of wear. This shall be expressed as the percentage of the 5 kilograms used in the test.

(3) For materials having a specific gravity below 2.20 the quantity used for the test shall be adjusted on a volume basis, retaining the specified number and size of pieces. For such materials a volume of 4,000 c. c. of the broken stone or broken slag shall be used.

2. ABRASION TEST FOR GRAVEL.

(1) The aggregate shall first be screened through screens having circular openings 2 inches, $1\frac{1}{2}$ inches, 1 inch, $\frac{3}{4}$ inch, and $\frac{1}{2}$ inch in diameter. The material of these sizes shall be washed and dried. The following weights of the dried stone shall then be taken: 1,250 grams of the size passing the 2-inch and retained on the $1\frac{1}{2}$-inch screen, 1,250 grams of the size passing the $1\frac{1}{2}$-inch and retained on the 1-inch screen, 1,250 grams passing the 1-inch screen and retained on the $\frac{3}{4}$-inch screen, 1,250 grams passing

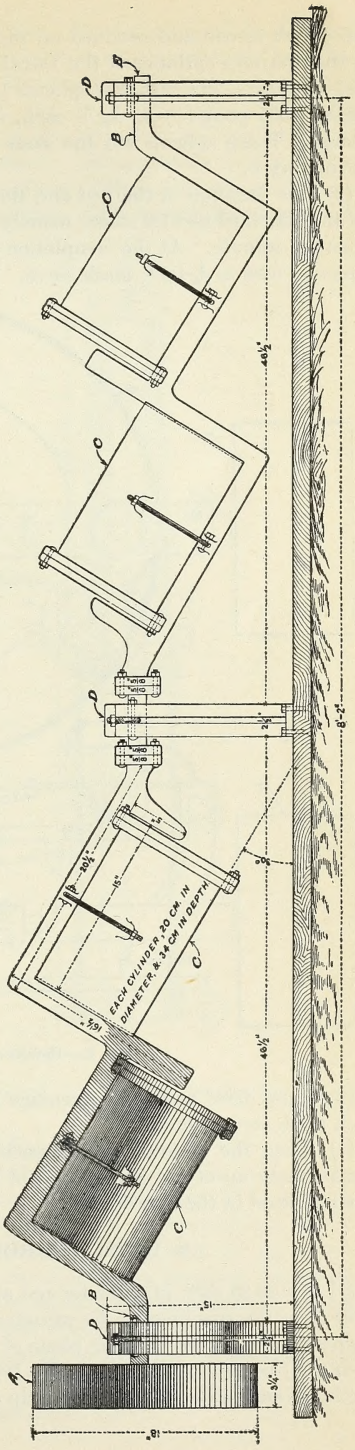


FIG. 1.—Abrasion machine—Deval type (front view).

the ¾-inch screen and retained on the ½-inch screen. This material shall be placed in the cast-iron cylinder of the Deval machine as specified for the standard abrasion test on stone. Six cast-iron spheres 1.875 inches in diameter and weighing approximately 0.95 pound (0.45 kg.), each, shall be placed in the cylinder as an abrasive charge. These spheres are the same as those used in the standard rattler test for paving brick.

(2) The duration of the test and the rate of rotation shall be the same as specified for the standard test for stone, namely, 10,000 revolutions at a rate of 30 to 33 revolutions per minute. At the completion of the test the material shall be taken out and screened over a $\frac{1}{16}$-inch mesh sieve. The material retained upon the sieve shall be

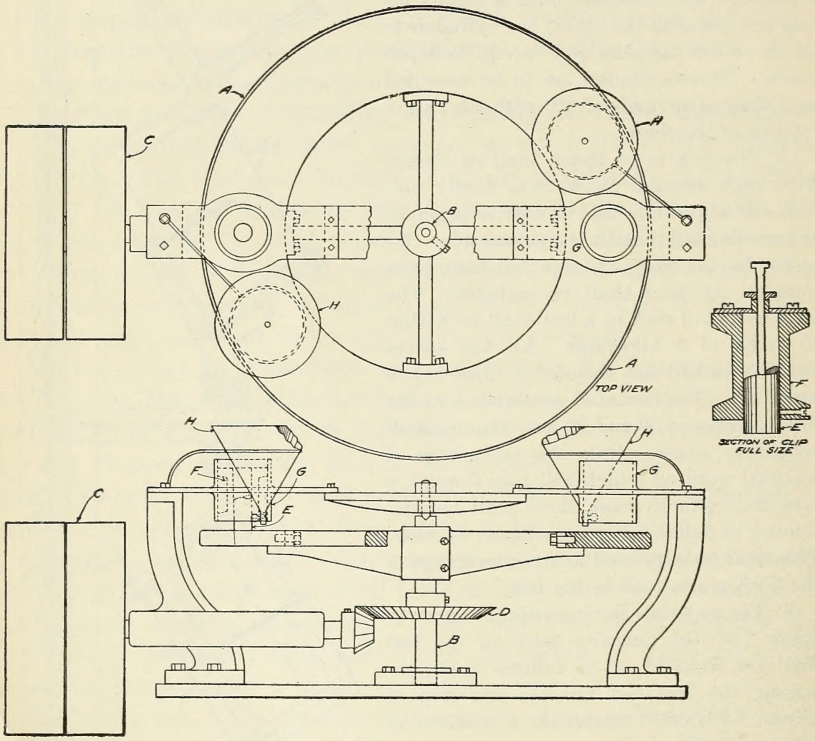


FIG. 2.—Details of Dorry hardness machine.

washed and dried and the percentage loss by abrasion of the material passing the $\frac{1}{16}$-inch mesh sieve calculated.

(3) When the material has a specific gravity below 2.20 a total weight of 4,000 grams made up of the four groups of sizes described above, instead of 5,000 grams, shall be used in the abrasion test.

3. DORRY HARDNESS TEST FOR ROCK.

(1) A core 25 mm. in diameter and about 10 cm. long shall be cut with the diamond drill from the specimen to be examined. The core should in every case be drilled perpendicular to the bedding plane of the rock. After thoroughly drying, the specimen shall be inserted in grip of the Dorry machine (fig. 2), leaving about 1 inch projecting from the lower end. The grip shall then be inserted in the sleeve so that the

lower end of the specimen rests on the steel disk. The funnel shall be filled with sand and the machine run until the lower end of the specimen has been worn down to the plane of the disk. The grip carrying the specimen shall then be removed, brushed free of dust, and accurately weighed. By means of small metal washers, any one or more of which may be slipped over the projecting rod of the grip, the initial weight shall be adjusted to exactly 1,250 grams. The grip shall then be replaced in the same position as before and the machine given 1,000 revolutions at the rate of 30 per minute, after which the grip and specimen shall be weighed again. The

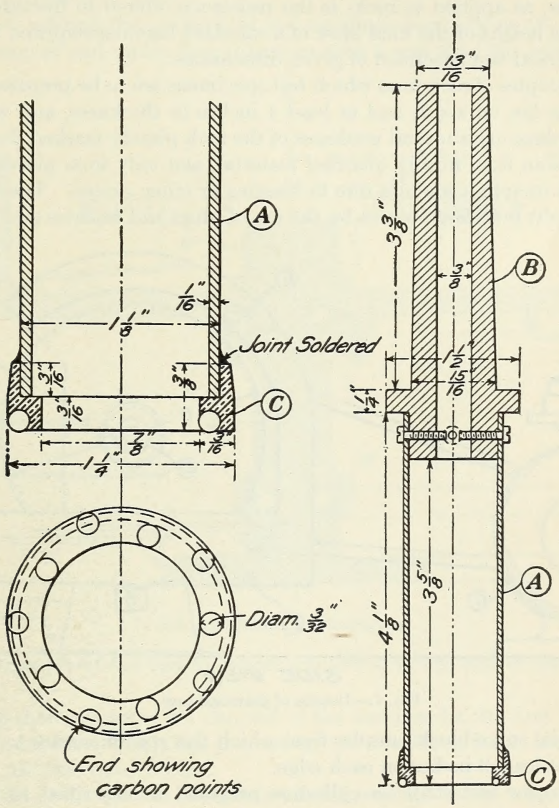


FIG. 3.—Diamond core drill.

test shall be repeated with the specimens reversed, in order to obtain the average hardness of the two ends.

(2) The sand used as the abrasive agent shall be a crushed quartz, screened to pass a standard sieve having 30 meshes per linear inch and to be retained on a standard sieve having 40 meshes per linear inch. Since it is almost impossible to obtain such a sand commercially, it is customary to specify a sand not more than 5 per cent of which will be retained on a No. 30 sieve and not more than 25 per cent of which will pass a No. 40 sieve. Sand known to the trade as No. 2½ quartz will usually fulfill these requirements. The ¼-inch opening in the funnel of the hardness machine will allow about 18 pounds of sand to pass through during a test.

(3) Calling the initial weight of grip plus specimen a, the final weight after 1,000 revolutions b,

$$\text{the coefficient of hardness} = 20 - \frac{(a - b)}{3}.$$

(4) The coefficient 20 is chosen as the standard of comparison to give about the same range of values as those obtained by the Deval abrasion test. The loss in weight is divided by 3 in order to avoid negative coefficients, since it is found that a specimen may lose as high as 60 grams in a single test.

4. TEST FOR TOUGHNESS OF ROCK.

(A. S. T. M. Standard Method, Serial Designation: D 3-18.)

(1) Toughness, as applied to rock, is the resistance offered to fracture by impact, expressed as the height of the final blow of a standard hammer required to cause fracture of a cylindrical test specimen of given dimensions.

(2) Quarry samples of rock from which test specimens are to be prepared shall measure at least 6 inches on a side and at least 4 inches in thickness, and when possible shall have the plane of structural weakness of the rock plainly marked thereon. Samples shall be taken from freshly quarried material, and only from pieces which show no evidences of incipient fracture due to blasting or other causes. The samples shall preferably be split from large pieces by the use of plugs and feathers and not by sledging. Commercial stone-block samples from which test specimens are to be prepared, shall measure at least 3 inches on each edge.

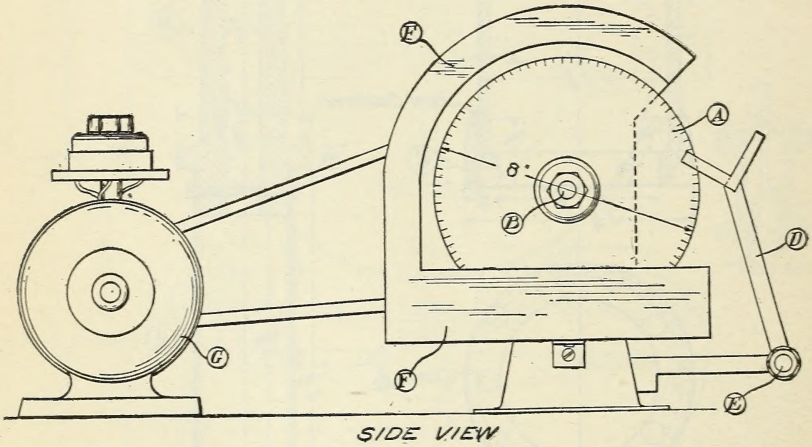


FIG. 4.—Details of diamond saw.

(3) Specimens for test shall be cylinders prepared as described in paragraph 4, 25 mm. in height and from 24 to 25 mm. in diameter. Three test specimens shall constitute a test set. The ends of the specimen shall be plane surfaces at right angles to the axis of the cylinder.

(4) One set of specimens shall be drilled perpendicular and another parallel to the plane of structural weakness of the rock, if such plane is apparent. If a plane of structural weakness is not apparent, one set of specimens shall be drilled at random. Specimens shall be drilled in a manner which will not subject the material to undue stresses and which will insure the specified dimensions. The ends of the cylinders may be sawed by means of a band or diamond saw,[1] or in any other way which will not induce incipient fracture, but shall not be chipped or broken off with a hammer. After sawing, the ends of the specimens shall be ground plane with water and carborundum or emery on a cast-iron lap (see fig. 5) until the cylinders are 25 mm. in length.

(5) Any form of impact machine which will comply with the following essentials may be used in making the test:

[1] Satisfactory forms of diamond drill and diamond saw are shown in figs. 3 and 4.

(*a*) A cast-iron anvil weighing not less than 50 kg., firmly fixed upon a solid foundation;

(*b*) A hammer weighing 2 kg., arranged so as to fall freely between suitable guides;

(*c*) A plunger made of hardened steel and weighing 1 kg., arranged to slide freely in a vertical direction in a sleeve, the lower end of the plunger being spherical in shape with a radius of 1 cm.;

(*d*) Means for raising the hammer and for dropping it upon the plunger from any specified height from 1 to not less than 75 cm., and means for determining the height of fall to approximately 1 mm.;

(*e*) Means for holding the cylindrical test specimen securely on the anvil without rigid lateral support and under the plunger in such a way that the center of its upper

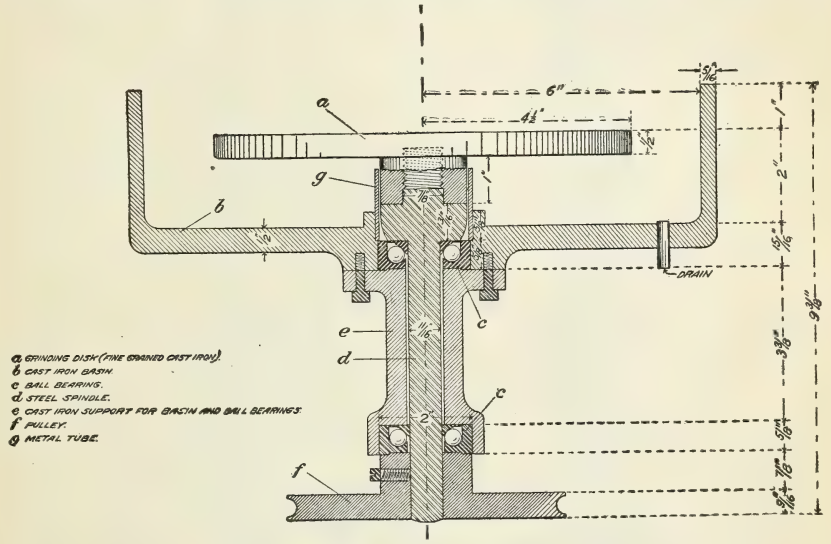


FIG. 5.—Details of grinding lap.

surface shall throughout the test be tangent to the spherical end of the plunger at its lowest point.

(6) The test shall consist of a 1 cm. fall of the hammer for the first blow, a 2 cm. fall for the second blow, and a fall increasing by 1 cm. for each succeeding blow until failure of the test specimen occurs.

(7) The height of the blow in centimeters at failure shall be the toughness of the test specimen. The individual and the average toughness of three test specimens shall be reported when no plane of structural weakness is apparent. In cases where a plane of structural weakness is apparent, the individual and average toughness of the three specimens in each set shall be reported and identified. Any peculiar condition of a test specimen which might affect the result, such as the presence of seams, fissures, etc., shall be noted and recorded with the test result.

5. TESTS FOR APPARENT SPECIFIC GRAVITY AND ABSORPTION OF STONE OR OTHER COARSE MATERIALS.

(1) The apparent specific gravity shall be obtained by weighing the water displaced by a sample of the material weighing approximately 1,000 grams, broken into pieces about 1¼ inches in diameter. The vessel to be used is shown in figure 7. It consists of a galvanized-iron cylinder closed at one end and measuring 5 inches in diameter by 8 inches high. A brass spout ½ inch in diameter is soldered into

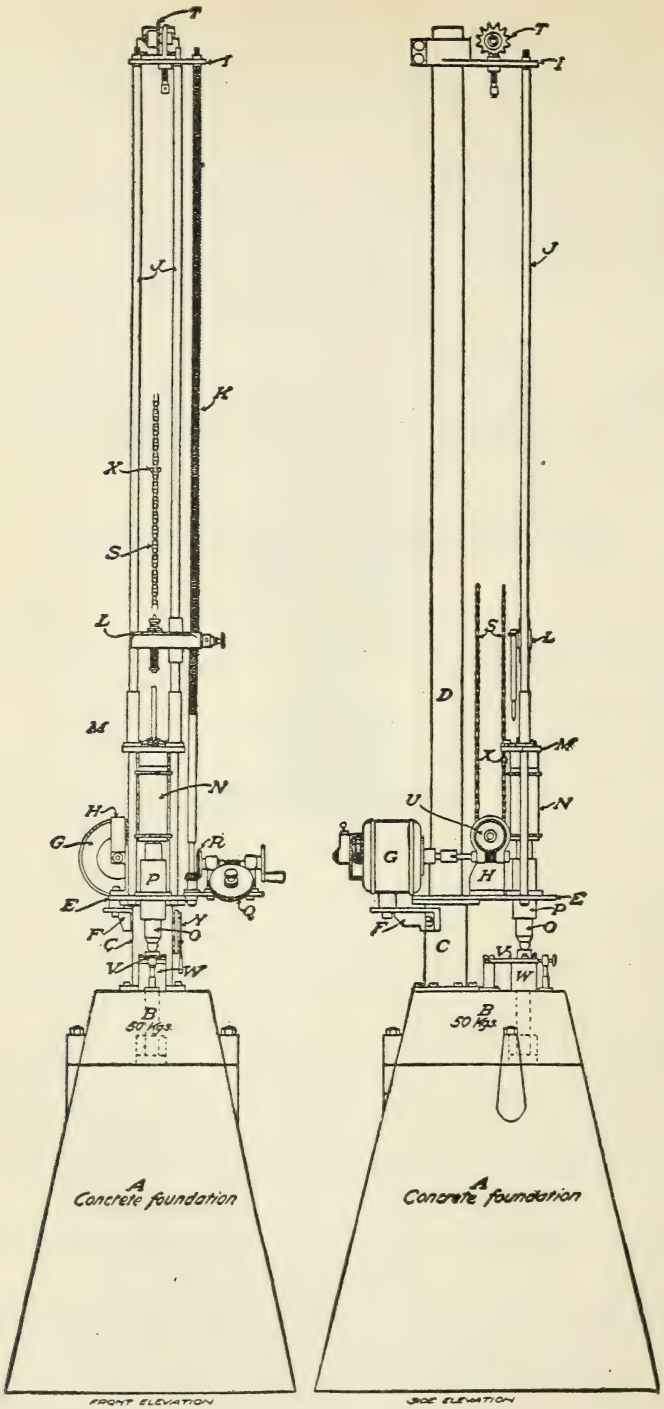


FIG. 6.—Details of Page impact testing machine.

the side of the cylinder 6 inches from the bottom. The spout is inclined at an angle of 2° with the horizontal and is 2½ inches long. A notch is filed across its lower end, as shown, to stop the drip from the displaced water. To determine the specific gravity, the dried and cooled sample shall be weighed to the nearest 0.5 gram and immersed in water for 24 hours. The pieces shall then be surface-dried individually with a towel, the sample reweighed and immediately placed in the cylinder, which has been previously filled to overflowing with water at room temperature.

(2) The weight of water displaced by the sample shall be used to calculate its apparent specific gravity. The difference between the original weight of the sample and its weight after 24 hours shall be used to determine the absorption.

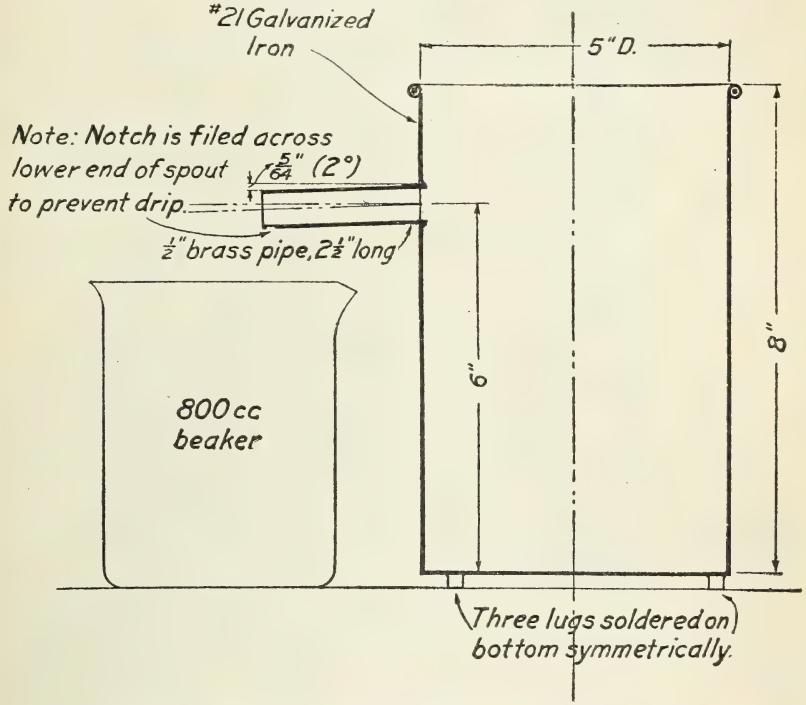


FIG. 7.—Vessel used in making specific-gravity and absorption tests.

6. TESTS FOR APPARENT SPECIFIC GRAVITY OF SAND, STONE, OR SLAG SCREENINGS AND OTHER FINE NON-BITUMINOUS HIGHWAY MATERIALS.

(A. S. T. M. Standard Methods, Serial Designation: D 55-19.)

(1) The following tests, "Le Chatelier" and "Jackson," are equally suited for use in determining the apparent specific gravity of sand, stone, and slag screenings and other fine non-bituminous highway materials and may be considered as alternates.

I. LE CHATELIER TEST.

(2) The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in figure 8. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

(3) (*a*) The flask shall be filled with either of the liquids to a point on the stem between zero and 1 c. c., and 64 grams of sand or other fine non-bituminous highway material of the same temperature as the liquid shall be slowly introduced, taking care that the material does not adhere to the inside of the flask above the liquid and to free the material from air by rolling the flask in an inclined position. After all material is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 grams of the material.

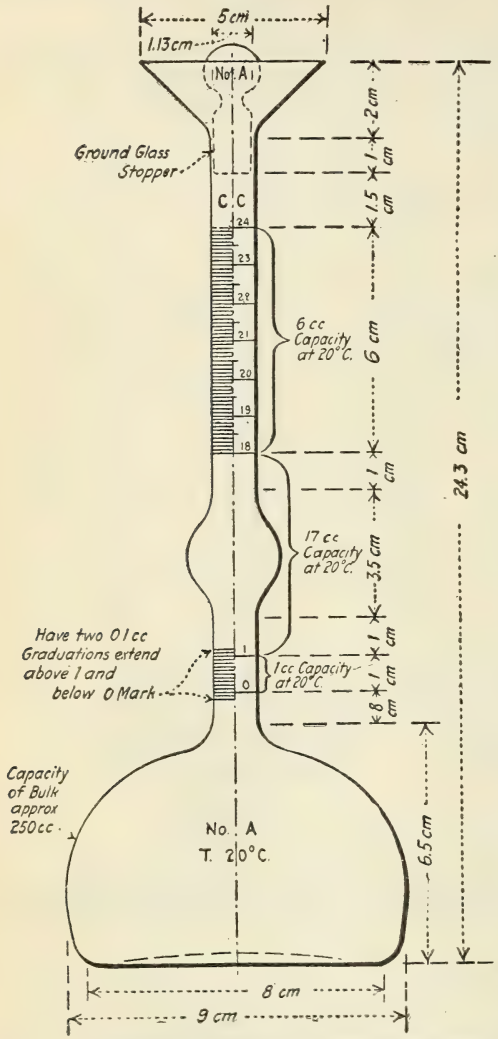


FIG. 8.—Le Chatelier apparatus for specific-gravity determinations.

The specific gravity shall then be obtained from the formula

$$\text{Sp. grav.} = \frac{\text{Weight of material (g)}}{\text{Displaced volume (c. c.)}}$$

(*b*) The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5° C. The results of repeated tests should agree with 0.01.

II. JACKSON TEST.

(4) The determination shall be made with a Jackson specific-gravity apparatus (illustrated in fig. 9), which shall consist of a burette, with graduations reading to 0.01 in specific gravity, about 23 cm. (9 inches) long and with an inside diameter of about 0.6 cm. (0.25 inch), which shall be connected with a glass bulb approximately 13 cm. (5.5 inches) long and 4.5 cm. (1.75 inches) in diameter, the glass bulb being of such size that from a mark on the neck at the top to a mark on the burette just below the bulb, the capacity is exactly 180 c. c. (6.09 liquid ounces); and an Erlenmeyer flask, which shall contain a hollow ground-glass stopper having the neck of the same bore as the burette, and shall have a capacity of exactly 200 c. c. (6.76 ounces) up to the graduation on the neck of the stopper.

(5) The method is as follows: (1) Dry at not more than 110° C. (230° F.) to a constant weight a sample weighing about 55 grams; (2) weigh 50 grams of the dry sample to 0.1 gram and pour it into the unstoppered Erlenmeyer flask, which shall be cleaned and dried before each determination; (3) fill the bulb and burette with kerosene, leaving just space enough to take the temperature by introducing a thermometer

through the neck; (4) remove the thermometer and add sufficient kerosene to fill exactly to the mark on the neck, drawing off any excess with the burette; (5) run into the flask about one-half of the kerosene in the bulb to remove air bubbles and then run in more kerosene, removing any material adhering to the neck of the flask, until the kerosene is just below the ground glass; (6) place the hollow ground-glass stopper in position and turn it to fit tightly and then run in kerosene exactly to the 200 c. c. (6.76 ounces) graduation on the neck, care being taken to remove all air bubbles in the flask; (7) read the specific gravity from the graduation on the burette, and the temperature of the oil in the flask, noting the difference between the temperature of the oil in the bulb before the determination and that of the oil in the flask after the determination; (8) make a temperature correction to the reading of the specific gravity in accordance with the table furnished by the manufacturer of the apparatus, adding the correction if the temperature of the kerosene has increased and subtracting it if the temperature of the kerosene has decreased.

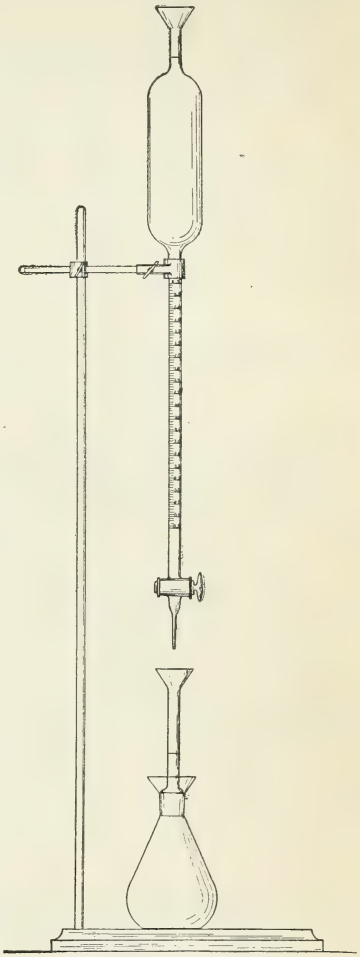


FIG. 9.—Jackson specific-gravity apparatus.

7. WEIGHT PER CUBIC FOOT AND VOID TESTS ON COARSE AGGREGATE.

(1) The weight per cubic foot of coarse aggregate shall be determined as follows: A cylindrical measure of at least one-fourth cubic foot capacity, with inside diameter approximately equal to inside height, or a box approximately cubical in shape and of not less than one-half cubic foot capacity shall be used. Ordinarily, the determination should be made on aggregate in air-dry condition. When the aggregate contains an appreciable amount of moisture, the percentage of water by weight shall be determined and recorded.

(2) About one-fourth of the total amount of aggregate necessary to fill the measure shall first be introduced in such manner as to avoid separation of sizes. This material shall then be shaken down by rocking the measure from side to side until no further settlement takes place. The process shall be repeated until the measure has been filled to overflowing, after which it shall be struck off level with the top with a straightedge and weighed.

The percentage of voids in the aggregate may be determined from the weight per cubic foot and specific gravity in the usual manner.

8. WEIGHT PER CUBIC FOOT TEST FOR FINE AGGREGATE.

(1) For determining weight per cubic foot of fine aggregate use a cylindrical metal measure having an inside diameter equal to the inside depth. A measure of capacity of one-fifth to one-half cubic foot is suggested, but a measure as small as one-twentieth cubic foot capacity may be used. Ordinarily the weight per cubic foot should be

determined on air-dry material. When the aggregate contains an appreciable amount of moisture the percentage of water by weight shall be determined and recorded.

(2) Fill the measure one-third full, puddle with 25 to 30 strokes from a ½-inch round steel bar 20 inches long, pointed at the lower end. Continue filling and puddling in like manner until the measure is full, then strike off the top by a rolling motion with the bar. Determine the weight of the contents of the measure and calculate the weight in pounds per cubic foot.

9. SIEVE ANALYSIS OF BROKEN STONE, GRAVEL, PEBBLES OR BROKEN SLAG.

(A. S. T. M. Standard Method, D 18–16, slightly modified.)

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing in pounds six times the diameter in inches of the largest holes required; (2) passing the sample through such of the following size screens having circular openings as are required or called for by the specifications, screens to be used in the order named: 8.89 cm. (3½ inches), 7.62 cm. (3 inches), 6.35 cm. (2½ inches), 5.08 cm. (2 inches), 3.81 cm. (1½ inches), 3.18 cm. (1¼ inches), 2.54 cm. (1 inch), 1.90 cm. (¾ inch), 1.27 cm. (½ inch), and 0.64 cm. (¼ inch); (3) determining the percentage by weight retained on each screen; and recording the mechanical analysis in the following manner:

	Per cent.
Passing 0.64 cm. (¼ inch) screen	.....
Passing 1.27 cm. (½ inch) screen and retained on a 0.64 cm. (¼ inch) screen	.....
Passing 1.90 cm. (¾ inch) screen and retained on a 1.27 cm. (½ inch) screen	.....
Passing 2.54 cm. (1 inch) screen and retained on a 1.90 cm. (¾ inch) screen	.....
.....	.....
	100.00

10. SIEVE ANALYSIS OF SAND OR FINE AGGREGATE.

(A. S. T. M. Standard, Serial Designation: D 7–18, slightly modified.)

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing not less than 100 grams and not more than 500 grams; (2) passing the sample through each of the mesh sieves [2] (American Society for Testing Materials standard sieves) specified in Table 1; (3) determining the percentage by weight retained on each sieve, the sifting being continued on each sieve until less than 1 per cent of the weight retained on each sieve shall pass through the sieve during the last minute of sifting; and (4) recording the mechanical analysis in the following manner:

	Per cent.
Passing 200-mesh sieve	.....
Passing 100-mesh sieve and retained on a 200-mesh sieve	.....
Passing 80-mesh sieve and retained on a 100-mesh sieve	.....
Passing 50-mesh sieve and retained on an 80-mesh sieve	.....
.....	.....
	100.00

[2] The order in which the sieves are to be used in the process of sifting is immaterial and shall be left optional; but in reporting results the order in which the sieves have been used shall be stated.

TABLE I.—*A. S. T. M. standard sieves.*

Mesh designation.	Unit of measure.	Actual mesh.	Opening.	Wire diameter.	Permissible variations.	
					Mesh.	Diameter.
10 [1]	Centimeter	3.9	0.200	0.056	0.04	0.005
	Inches	9.9	.079	.022	.1	.002
20	Centimeter	8	.085	.040	.2	.0015
	Inches	20.3	.0335	.0157	.5	.0006
30	Centimeter	12.0	.050	.033	.4	.0012
	Inches	30.5	.0197	.0130	1.0	.0005
40 [1]	Centimeter	16	.036	.026	.6	.0010
	Inches	40.6	.0142	.0102	1.5	.0004
50	Centimeter	20	.029	.021	.8	.0010
	Inches	50.8	.0114	.0083	2	.0004
80 [1]	Centimeter	31	.017	.015	1	.0008
	Inches	78.7	.0067	.0059	3	.0003
100 [1]	Centimeter	39	.014	.0116	1	.0008
	Inches	99.1	.0055	.0046	3	.0003
200 [1]	Centimeter	79	.0074	.0053	3	.0005
	Inches	200.7	.0029	.0021	8	.0002

[1] The ¼-inch circular opening screen and these sieves are recommended for the sieve analysis except for fine aggregate used in bituminous surfaces.

11. SIEVE ANALYSIS OF MIXTURES OF FINE AND COARSE AGGREGATES.

(A. S. T. M. Standard Method, Serial Designation: D 19–16, slightly modified.)

The method shall consist of (1) drying at not over 110°C. (230° F.) to a constant weight a sample weighing in pounds six times the diameter in inches of the largest holes required; (2) separating the sample by the use of a screen having circular openings 0.64 cm. (¼ inch) in diameter; (3) examining the portion retained on the screen in accordance with the standard method for making a sieve analysis of broken stone, gravel, pebbles, or broken slag (test No. 9), examining the portion passing this screen in accordance with the standard method for making a mechanical analysis of sand or other fine aggregate (test No 10); (4) and recording the mechanical analysis in the following manner:

	Per cent.
Passing 200-mesh sieve	.....
Passing 100-mesh sieve and retained on a 200-mesh sieve	.....
Passing 80-mesh sieve and retained on a 100-mesh sieve	.....
.....	.....
Passing 10-mesh sieve and retained on a 20-mesh sieve	.....
Passing 0.64-cm. (¼-inch) screen and retained on a 10-mesh sieve	.....
Passing 1.27-cm. (½-inch) screen and retained on a 0.64-cm. (¼-inch) screen	.....
Passing 1.90-cm. (¾-inch) screen and retained on a 1.27-cm. (½-inch) screen	.....
.....	.....
	100

In the sieve analysis of the sand fraction, the following sizes of sieves shall be used except for fine aggregate used for bituminous surfaces: ¼-inch circular opening, 10-mesh, 40-mesh, 80-mesh, 100-mesh, and 200-mesh.

12. TESTS FOR DETERMINING THE AMOUNT OF CLAY AND SILT IN SAND OR FINE AGGREGATE, IN GRAVEL AND IN SAND-CLAY, TOP SOIL, OR SEMIGRAVEL.

A. SAND OR FINE AGGREGATE.

(1) The specification covers the determination of the quantity of clay and silt in natural sand to be used in road construction.

(2) The sample as received shall be moistened and thoroughly mixed, then dried to constant weight at a temperature between 100° C. (212° F.) and 110° C. (230° F.).

(3) Five hundred (500) grams representative of the dried sample shall be placed in a dried and accurately weighed pan or vessel having vertical sides and provided with a pouring lip. This pan shall be substantially 22.9 cm. (9 inches) in diameter by not less than 10.2 cm. (4 inches) deep. Pour sufficient water in the pan to cover the sand (about 225 c. c.). Agitate vigorously for fifteen (15) seconds. Allow to settle for fifteen (15) seconds and then pour off the water into a tared evaporating dish, taking care not to pour off any sand. Repeat until the wash water is clear, using a glass rod to stir the material for the last few washings.

(4) Thoroughly dry the pan and washed sand in an oven at between 100° C. (212° F.) and 110° C. (230° F.), weigh and determine net weight of sand.

(5) Compute the per cent of clay and silt as follows:

$$\frac{\text{Original weight} - \text{weight after washing}}{\text{Original weight}} \times 100 = \text{per cent of clay and silt.}$$

For a check on the results, evaporate the wash water to dryness and weigh the residue.

$$\frac{\text{Weight of residue}}{\text{Original weight}} \times 100 = \text{per cent of clay and silt.}$$

B. GRAVEL.

(6) The specification covers the determination of the quantity of clay and silt in natural gravel to be used in road construction.

(7) The sample as received shall be moistened and thoroughly mixed, then dried to constant weight at a temperature between 100° C. (212° F.) and 110° C. (230° F.).

(8) A representative portion of the dry material, weighing not less than 50 times the weight of the largest stone in the sample, shall be selected from the sample, and placed in a dried and accurately weighed pan or vessel. The pan shall be 30.2 cm. (12 inches) in diameter by not less than 10.2 cm. (4 inches) deep, as nearly as may be obtained. Pour sufficient water in the pan to cover the gravel and agitate vigorously for fifteen (15) seconds, using a trowel or stirring rod. Allow to settle for fifteen (15) seconds, and then pour off the water into a tared evaporating dish, being careful not to pour off any sand. Repeat until the wash water is clear.

(9) Dry the washed material to constant weight in an oven at between 100° C. (212° F.) and 110° C. (230° F.), weigh, and determine net weight of gravel.

(10) Compute the per cent of clay and silt as follows:

$$\frac{\text{Original weight} - \text{weight after washing}}{\text{Original weight}} \times 100 = \text{per cent of clay and silt.}$$

C. SAND-CLAY, TOP SOIL, AND SEMIGRAVEL.

(11) Dry 500 grams of the material at a temperature below 350° F. (176.6° C.) to a constant weight. Gently pulverize to break down soft clods or masses, but not to grind or break hard material. Pass through a 10-mesh sieve, weigh the coarse residue, and record as "coarse material." Use the material passing the 10-mesh sieve as the starting point of a percentage analysis as follows:

(12) Weigh out two samples of 50 grams of this material for duplicate analysis. Place each in a tared wide-mouth bottle (5 to 6 cm. diameter and about 12 to 15 cm.

high). Add about 5 c. c. of dilute ammonia water and about 200 c. c. of water. Close with a cork or glass stopper and shake thoroughly for 20 minutes. Allow the sample to settle eight minutes and decant carefully or siphon off the supernatant liquid to a depth of 8 cm. below the surface of the liquid. (The depth of the liquid in the bottle should be sufficient to leave about 4 cm. below the point of siphoning.) Fill the bottle again with water, shake for three minutes, allow settlement, and siphon off as before. Repeat the process until the supernatant liquid is clear. Be careful to wash the stopper and neck of the bottle free from coarse material before decanting.

(13) Dry the bottle and washed material to constant weight at between 100° C. (212° F.) and 110° C. (230° F.), weigh and determine the net weight of washed material.

$$\frac{\text{Original weight} - \text{washed weight}}{\text{Original weight}} \times 100 = \text{per cent clay and silt.}$$

(14) As a check the washings drawn off shall be collected and evaporated to dryness for direct recovery of the fine sediment classed as clay and silt.

$$\frac{\text{Weight of residue}}{\text{Original weight}} \times 100 = \text{per cent clay.}$$

The determinations on the two samples shall check within 1 per cent to be acceptable.

13. TESTS FOR SEMIGRAVEL, TOP SOIL, AND SAND-CLAY.

The amount of clay and silt is first determined in accordance with test No. 12, then proceed as follows:

(1) Wash the contents of the bottle cleanly into a porcelain evaporating dish and carry to dryness on a water bath. The dried residue shall be carefully scraped from the dish and passed through a nest of 20, 60, 100, and 200 mesh sieves. The residue retained on each sieve shall be weighed and recorded as sand of the respective sizes. Their sum constitutes the total "sand." The residue passing the 200-mesh sieve and caught in the pan shall be weighed and recorded as "silt." Duplicate samples should check within 1 per cent.

(2) The coarse material shall be examined for hardness and with the magnifying glass to identify its character as quartz, hard iron compounds, feldspar, schistose material, or indurated clay. Hard quartz or iron gravels are valuable in themselves and as indicating the quality of the finer aggregate. Feldspar, mica, and clay nodules are worthless and indicate that the accompanying soil is poor for road building.

(3) The sands shall be examined with the magnifying glass for identification as quartz and for the presence of mica scales or feldspar needles. If mica or feldspar is present in appreciable amounts the sample should be rejected.

(4) When the clay is recovered by evaporation it can be examined for tenacity by cementing together two glass plates, each 1 inch wide, set at right angles, with a layer of clay whose thickness is fixed by a fine bent wire laid between the plates. The moist clay shall cover the wire on one plate, and the other plate shall be squeezed down tightly on the wire. After drying, the one plate shall be held firmly against cleats, wire slings shall be run symmetrically from the ends of the upper plate to one arm of a beam balance, and the tension necessary to separate the plates shall be given by shot or weights in the other pan of the balance. This test is tedious, and is of service chiefly on low-grade samples which are of doubtful efficiency, but which represent the only available material for local construction.

(5) Approximate tests for tenacity of mixture can be made as follows:

Make cylinders 25 mm. in height and 25 mm. in diameter from the material passing the 10-mesh sieve. Work the material into a stiff mud and mold under 132 kg. per square centimeter pressure. Dry thoroughly at 100° C. (212° F.) and break by the small Page impact machine for testing cementing value, using a 1-kg. hammer and 1-cm. drop. Record the number of strokes as the relative measure of tenacity.

Mix 50 grams of the material passing the 10-mesh sieve with —[3] grams of water and knead with the hands into a spherical ball. Measure the diameter. Let this ball drop from a height of —[3] cm. on a flat slab. Measure and record the reduction in diameter and examine the surface for cracks.

Usually the plastic character and adhesiveness of a good road soil can be judged by the feeling of the mud made from the material, its adherence to the hands and its stretch under light pulling.

14. TESTS FOR QUALITY OF WATER TO BE USED IN CONCRETE.

(1) *Acidity and alkalinity.*—The acidity and alkalinity test shall be made by immersing strips of blue and red litmus paper in a vessel of the water for a period of five minutes and noting color. A marked reversal in color indicates excessive acidity or alkalinity and the necessity for further tests.

(2) *Total solids and inorganic matter.*—Five hundred (500) cubic centimeters of the water shall be evaporated to dryness in a weighed dish. For this purpose a platinum dish of 100 to 200 c. c. capacity is found most convenient. The dish shall be nearly filled with the water and placed on a water bath, additional portions of the sample of water being added from time to time until 500 c. c. have been used. The contents of the dish shall be evaporated to dryness and the dish and contents cooled in a dessicator and weighed. The weight of the residue in grams divided by 5 is the per cent of total solids in the water.

(3) The total solids obtained as described, may consist of organic matter, of inorganic matter, or of combinations of organic and inorganic matter. The platinum dish shall be ignited at low red heat, and the darkening of the residue during the early stage of the ignition usually indicates the presence of organic matter. The per cent loss on ignition at low red heat will usually be an indication of the amount of organic matter, but it should be noted that some mineral salts tend to volatilize or partly decompose on heating.

(4) The determination of the decomposition of the mineral matter in the water usually requires a complete chemical analysis of the total solids obtained by the evaporation of 500 c. c., or more, of the water, and is not generally undertaken except when the percentage of total solids is large, or the water appears to give abnormal tests in other respects.

(5) A comparison of the given water with a water of known satisfactory quality can be obtained by making standard soundness, time of setting, and 1:3 mortar strength tests with standard sand, using the same cement of standard quality with each water. (Suggested limits for the last-named test are as follows: Any indication of unsoundness, marked change in time of setting, or a variation of more than 10 per cent in strength from results obtained with mixtures containing the water of satisfactory quality, shall be sufficient cause for rejection of the water under test.)

15. TEST FOR ORGANIC IMPURITIES IN CONCRETE AGGREGATES.

The test recommended is described in the "Proceedings of the American Society for Testing Materials, Philadelphia, Pa., Volume XIX, part 1, 1919, Appendix to Report of Committee C–9 on Concrete and Concrete Aggregates."

(1) The test as usually made consists of shaking the sand thoroughly in a dilute solution of sodium hydroxide (NaOH) and observing the resultant color after the mixture has been allowed to stand for a few hours. Fill a 12-oz. graduated prescription bottle to the 4½-oz. mark with the sand to be tested. Add a 3 per cent solution of sodium hydroxide until the volume of the sand and solution, after shaking, amounts to 7 ounces. Shake thoroughly and let stand for 24 hours. Observe the color of the clear

[3] No definite weight of water or height of fall recommended.

liquid above the sand. A good idea of the quality of the sand can be formed earlier than 24 hours, although this period is believed to give best results.

(2) If the solution resulting from this treatment is colorless, or has a light yellowish color, the sand may be considered satisfactory in so far as organic impurities are concerned. On the other hand, if a dark-colored solution of a color deeper than that indicted is produced, the sand should not be used in high-grade concrete such as that required in roads and pavements, or in building construction.

* * * * * * *

(3) Color values: While it is not practicable to give exact values for the reduction in strength corresponding to the different colors of solution, the tests made thus far show this relation to be about as follows:

Color No.[1]	Reduction in compressive strength of 1 : 3 mortar at 7 and 28 days.
	Per cent.
Figure 1	None.
Figure 2	10 to 20.
Figure 3	15 to 30.
Figure 4	25 to 50.
Figure 5	50 to 100.

[1] See Plate V, Proceedings of the American Society for Testing Materials, vol. xix, part 1, Report of Committee C-9, for Color Scale.

(4) Washing dirty sands has the effect of greatly reducing the quantity of organic impurities. However, even after washing, sands should be examined in order to determine whether the organic impurities have been reduced to harmless proportions.

The following list includes sufficient apparatus for making five field tests at a time: Five 12-oz. graduated prescription bottles; Stock of 3 per cent solution of sodium hydroxide (dissolve 1 oz. of sodium hydroxide in enough water to make 32 oz.)

This test does not give satisfactory results when lignite is present in the sand.

16. TEST FOR MORTAR MAKING QUALITY OF FINE AGGREGATES.

(1) When the fine aggregate is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1 : 3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a strength in tension and compression of at least —— [4] per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

(2) Preliminary acceptance samples shall be subjected to both 7 and 28 day tests and acceptance based thereupon. Samples tested during the progress of the work shall be accepted on the basis of the 7-day test.

17. STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT.

(A. S. T. M. Standard Method, Serial Designation: C 9-17.)

SPECIFICATIONS.

(1) Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

[4] It is recommended that the strength ratio be 100 per cent for this purpose.

CHEMICAL PROPERTIES.

(2) The following limits shall not be exceeded:

	Per cent.
Loss on ignition	4.00
Insoluble residue	.85
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	5.00

PHYSICAL PROPERTIES.

(3) The specific gravity of cement shall not be less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

(4) The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

(5) A pat of neat cement shall remain firm and hard and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

(6) The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

(7) The average tensile strength, in pounds per square inch, of not less than three standard mortar briquettes (see par. 51) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test.	Storage of briquettes.	Tensile strength per square inch.
Days.		*Pounds.*
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

(8) The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

PACKAGES, MARKING, AND STORAGE.

(9) The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

(10) The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment and in a suitable weather-tight building which will protect the cement from dampness.

INSPECTION.

(11) Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

REJECTION.

(12) The cement may be rejected if it fails to meet any of the requirements of these specifications.

(13) Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

(14) Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

(15) Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment as shown by weighing 50 packages taken at random is less than that specified, the entire shipment may be rejected.

TESTS.

Sampling.

(16) Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 pounds.

(17) (*a*) If sampled in cars one test sample shall be taken from each 50 barrels or fraction thereof. If sampled in bins one sample shall be taken from each 100 barrels.

(*b*) If sampled in cars one sample shall be taken from one sack in each 40 sacks (or 1 barrel in each 10 barrels) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 barrels.

(18) Cement may be sampled at the mill by any of the following methods that may be practicable as ordered:

(*a*) From the conveyor delivering to the bin at least 8 pounds of cement shall be taken from approximately each 100 barrels passing over the conveyor.

(*b*) Proper sampling tubes inserted vertically may be used for sampling cement in filled bins to a maximum depth of 10 feet. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) Sufficient cement shall be drawn from the discharge openings in filled bins to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

(19) Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample; break up lumps and remove foreign materials.

Chemical Analysis.

loss on ignition.

(20) One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25 c. c. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900° and 1,000° C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

(21) A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent.

INSOLUBLE RESIDUE.

(22) To a 1-gram sample of cement shall be added 10 c. c. of water and 5 c. c. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 c. c. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete.

The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 c. c. of a 5 per cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1:9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

(23) A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent.

SULPHURIC ANHYDRIDE.

(24) One gram of the cement shall be dissolved in 5 c. c. of concentrated hydrochloric acid diluted with 5 c. c. of water, with gentle warming; when solution is complete, 40 c. c. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 c. c., heated to boiling, and 10 c. c. of a hot 10 per cent solution of barium chloride shall be added slowly, drop by drop from a pipette, and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulphate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulphuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulphuric anhydride instead of using a separate sample.

(25) A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2 per cent.

MAGNESIA.

(26) To 0.5 gram of the cement in an evaporating dish shall be added 10 c. c. of water to prevent lumping and then 10 c. c. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150° or even 200° C. for one-half to one hour. The residue shall be treated with 10 c. c. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered with the solution digested for 10 minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water. Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese which may be present shall be added to the filtrate (about 250 c. c.). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitation vessel and dissolved in 10 c. c. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 c. c., and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and alumi-

num, reduced in volume if need be, 1 c. c. of ammonium hydroxide shall be added, the solution brought to boiling, 25 c. c. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 c. c., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 c. c. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 c. c., 1 c. c. of a saturated solution of sodium-ammonium-hydrogen phospate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

(27) A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5 per cent.

DETERMINATION OF SPECIFIC GRAVITY.

(28) The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in figure 7. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baume, shall be used in making this determination.

(29) The flask shall be filled with either of these liquids to a point on the stem between zero and 1 c. c., and 64 grams of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck, the difference between readings is the volume displaced by 64 grams of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (c. c.)}}$$

(30) The flask during the operation shall be kept immersed in water in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5° C. The results of repeated tests should agree within 0.01.

(31) The determination of specific gravity shall be made on the cement as received. If it falls below 3.10, a second determination shall be made after igniting the sample as described in section 20.

DETERMINATION OF FINENESS.

(32) Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire and mounted without distortion on frames not less than 1½ inches below the top of the frame. The sieve frames shall be circular, approximately 8 inches in diameter, and may be provided with a pan and cover.

(33) A standard No. 200 sieve is one having nominally a 0.0029-inch opening and 200 wires per inch standardized by the United States Bureau of Standards and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 inch in width. The diameter of the wire should be 0.0021 inch, and the average diameter shall not be outside the limits 0.0019 to 0.0023 inch. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similar graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

(34) The test shall be made with 50 grams of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position, so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the upstroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 gram passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

(35) Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in paragraph 34.

(36) A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.[5]

MIXING CEMENT PASTES AND MORTARS.

(37) The quantity of dry material to be mixed at one time shall not exceed 1,000 grams nor be less than 500 grams. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 c. c. of water=1 gram). The dry materials shall be weighed, placed upon a nonabsorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of one-half minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute. During the operation of mixing, the hands should be protected by rubber gloves.

(38) The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C. (70° F.).

NORMAL CONSISTENCY.

(39) The Vicat apparatus consists of a frame A (fig. 10) bearing a movable rod, B, weighing 300 grams, one end, C, being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle, D, 1 mm. in diameter, 6 cm. long. The rod is

[5] Article 36 is to be withdrawn from these specifications, effective Jan. 1 1921.

reversible, and can be held in any desired position by a screw, E, and has midway between the ends a mark, F, which moves under a scale (graduated to millimeters) attached to the frame A. The paste is held in a conical, hard-rubber ring, G, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate, H, about 10 cm. square.

(40) In making the determination, 500 grams of cement, with a measured quantity of water, shall be kneaded into a paste, as described in section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 inches apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed

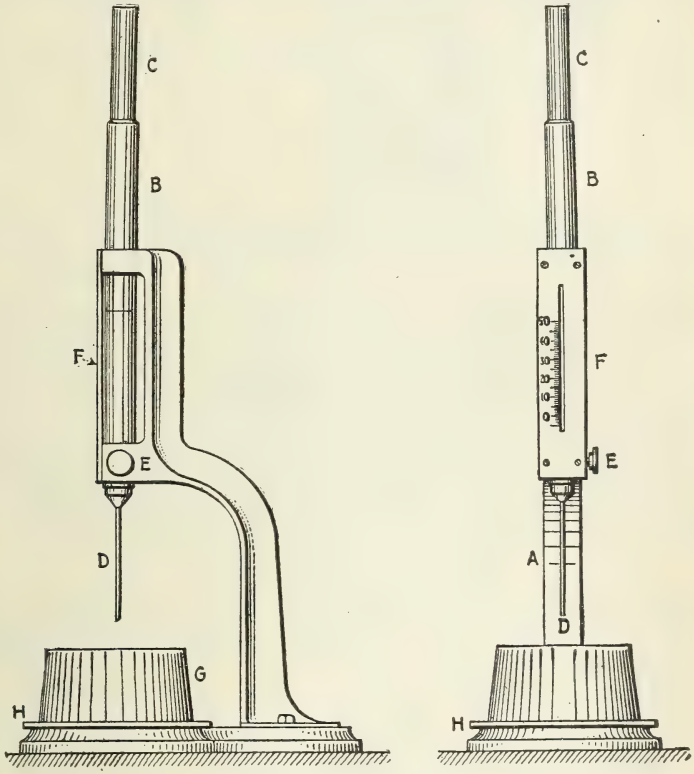


FIG. 10.—Vicat apparatus.

on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in one-half minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

(41) The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in the following table, the values being in percentage of the combined dry weights of the cement and standard sand.

Percentage of water for standard mortars.

For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.	For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.	For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.	For neat cement paste.	For 1 to 3 mortars of standard Ottawa sand.
18	9.5	21	10.0	24	10.5	27	11.0
19	9.7	22	10.2	25	10.7	28	11.2
20	9.8	23	10.3	26	10.8	29	11.3

DETERMINATION OF SOUNDNESS.

(42) A steam apparatus, which can be maintained at a temperature between 98° and 100° C., or one similar to that shown in figure 11, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

(43) A pat from cement paste of normal consistency about 3 inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 inches square, and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

(44) The pat shall then be placed in an atmosphere of steam at a temperature between 98° and 100° C. upon a suitable support 1 inch above boiling water for 5 hours.

(45) Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

DETERMINATION OF TIME OF SETTING.

(46) The following are alternate methods, either of which may be used as ordered:

(47) The time of setting shall be determined with the Vicat apparatus described in paragraph 39 (see fig. 10).

(48) A paste of normal consistency shall be molded in the hard-rubber ring G as described in paragraph 40, and placed under the rod B, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in one-half minute after being released; and the final set when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

(49) The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in figure 12 (b).

(50) The time of setting shall be determined as follows: A pat of neat cement paste with about a 3-inch diameter and one-half inch thick, with a flat top, mixed to a

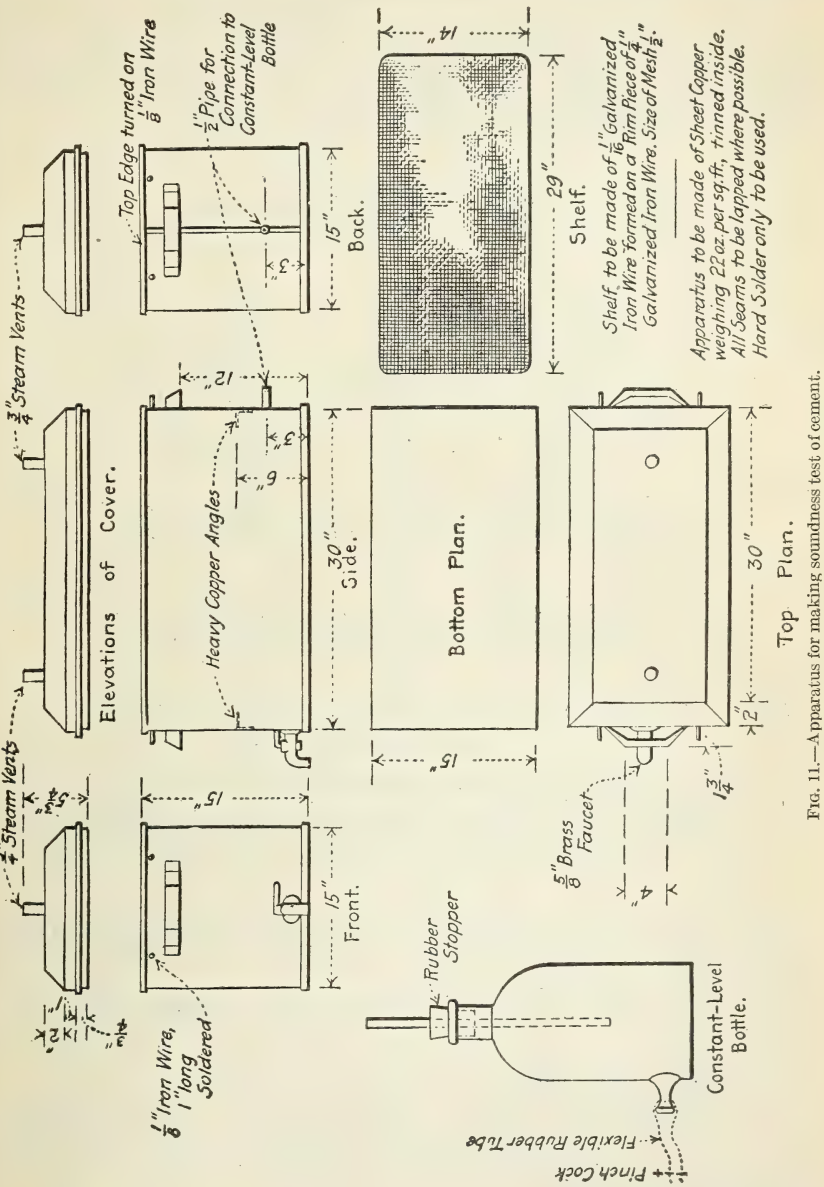


FIG. 11.—Apparatus for making soundness test of cement.

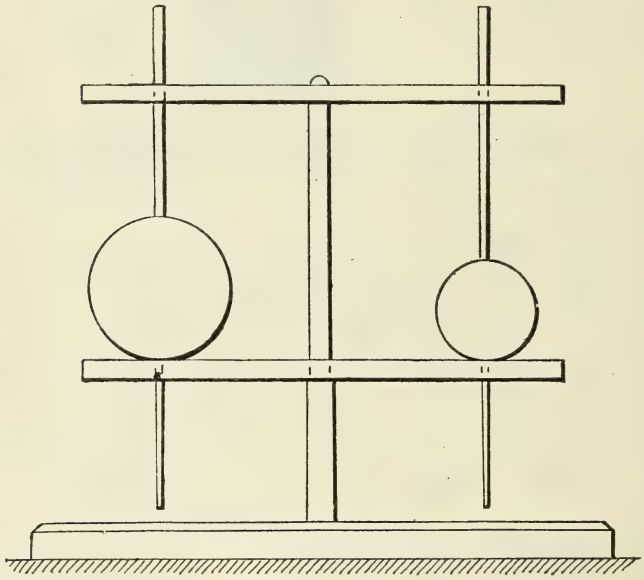
normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° F.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle one-twelfth inch in diameter, loaded to weigh one-fourth pound. The final

set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle one twenty-fourth inch in diameter, loaded to weigh 1 pound. In making the test, the needles shall be held in a vertical position, and applied lightly to the surface of the pat.

TENSION TESTS.

(51) The form of test piece shown in figure 13 shall be used. The molds shall be made of noncorroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in figure 14. Molds shall be wiped with an oily cloth before using.

(a) Pot with top surface flattened for determining time of setting by Gillmore method.



(b) Gillmore needles.

FIG. 12.

(52) The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained at a cost of 2 cents per pound, f. o. b. cars, Ottawa, Ill.

(53) This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 grams pass the No. 30 sieve after one minute continuous sieving of a 500-gram sample.

(54) The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 inch and the average diameter shall not be outside the limits of 0.0160 and 0.0170 inch.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 inch, and the average diameter shall not be outside the limits 0.0105 to 0.0115 inch.

(55) Immediately after mixing, the standard mortar shall be placed in the molds, pressed firmly with the thumbs, and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold, and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing, and smoothing off repeated.

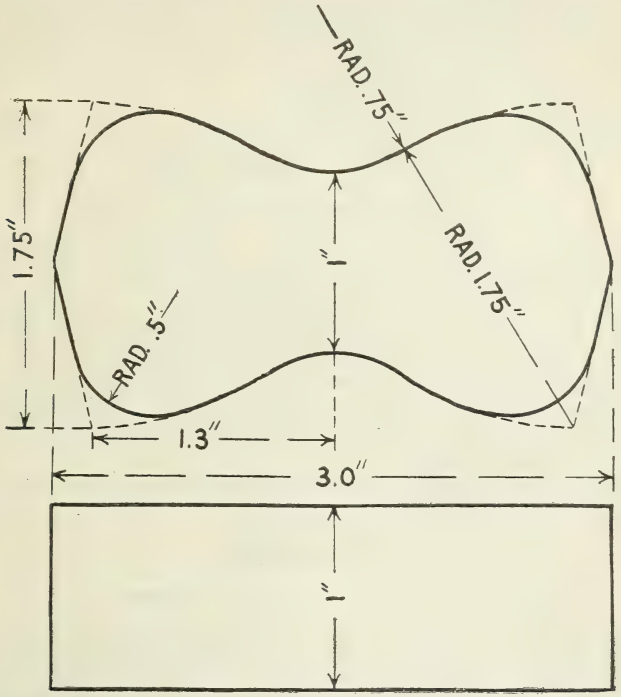


FIG. 13.—Form of briquette as recommended by the committee on uniform tests of cement of the American Society of Civil Engineers.

(56) Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 pounds per minute.

(57) Testing machines should be frequently calibrated in order to determine their accuracy.

(58) Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all tests pieces made from the same sample

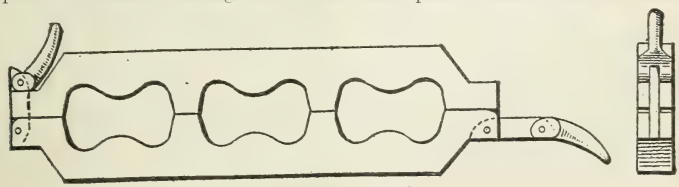


FIG. 14.—Gang mold.

and broken at the same period, shall not be considered in determining the tensile strength.

STORAGE OF TEST PIECES.

(59) The moist closet may consist of a soapstone, slate, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with

felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with nonabsorbent shelves, on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

(60) Unless otherwise specified all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

(61) The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of noncorroding material.

(62) The air and water shall be maintained as nearly as practicable at a temperature of 21° C. (70° F.).

18. TESTS FOR PAVING BRICK.

(A. S. T. M. Standard Method, Serial Designation: C 7–15.)

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side, shall be determined by the following procedure:

I. The rattler test for the purpose of determining whether the material as a whole possesses to a sufficient degree strength, toughness, and hardness.

II. Visual inspection for the purpose of determing whether the physical properties of the material as to dimensions, accuracy, and uniformity of shape and color are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

I. THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TESTS.

(1) *Place of sampling.*—In general, where a shipment of bricks involving a quantity of less than 100,000 is under consideration, the sampling shall be done at the factory prior to shipment. Bricks accepted as the result of test prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Part II, visual inspection.

(2) *Method of selecting samples.*—In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection, as provided in Part II, except that where controversy arises whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

(3) *Number of samples per lot.*—In general, one sample of 10 bricks shall be tested for every 10,000 bricks contained in the lot under consideration; but where the total quantity exceeds 100,000 the number of samples tested may be fewer than 1 per 10,000 provided that they shall be distributed as uniformly as practicable over the entire lot.

(4) *Shipment of samples.*—Samples which must be transported long distances by freight or express shall be carefully put up in packages holding not more than 12 bricks each. When more than 6 bricks are shipped in one package, it shall be so arranged as to carry two parallel rows of bricks side by side and these rows shall be

separated by a partition. In event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining 10 sound undamaged bricks.

(5) *Storage and care of samples.*—Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° F. before testing.

THE CONSTRUCTION OF THE RATTLER.

(6) *General design.*—The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame, and driving mechanism as herein described.

(7) *The barrel.*—The barrel of the machine shall be made up of the heads, head liners, staves, and stave liners.

The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ inches in diameter, and shall have a bearing 6 inches in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-inch shafts, and shall be key-seated for two keys, each one-half by three-eighths inch and spaced 90° apart. The shaft shall be a snug fit, and when keyed shall be entirely free of lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ inches in the head for the driving end of the rattler, and $11\frac{3}{8}$ inches for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ inches.

The heads shall be not less than three-fourths inch thick, nor more than seven-eighths inch thick. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ inches in diameter. Each head shall be provided with flanges not less than three-fourths of an inch thick and extending outward $2\frac{1}{2}$ inches from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge so as to provide for two three-fourths-inch bolts at each end of each stave, said slots to be thirteen-sixteenths of an inch wide and $2\frac{3}{4}$ inches center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace three-eighths of an inch thick, extending down the outward side of the head not less than 2 inches.

There shall be for each head a cast-iron head liner 1 inch in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ inches in diameter. This head liner shall be fastened to the head by seven five-eighths-inch cap screws, through the head from the outside. Whenever these head liners become worn down one-half inch below their initial surface level at any point of their surface, they shall be replaced with new ones. The metal of these head liners shall be hard machinery iron and should contain not less than 1 per cent of combined carbon.

The staves shall be made of 6-inch medium-steel structural channels $27\frac{1}{4}$ inches long and weighing 15.5 pounds per linear foot. The staves shall have two holes thirteen-sixteenths inch in diameter, drilled in each end, the center line of the holes being 1 inch from the end and $1\frac{3}{8}$ inches either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed five-sixteenths of an inch.

The interior or flat side of each stave shall be protected by a liner three-eighths of an inch thick by $5\frac{1}{2}$ inches wide by $19\frac{3}{4}$ inches long. The liner shall consist of medium-steel plate, and shall be riveted to the channel by three one-half-inch rivets, one of

which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 inches from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once reriveted.

Any test at the expiration of which a stave liner is found detached from the stave or seriously out of position shall be rejected. When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged with 400 pounds of shot of the same sizes and in the same proportions as provided in section 9, and shall then be run for 18,000 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive but not contiguous, for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative condition of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 inches long, inside measurement, between headliners. The liners of the staves shall be so placed as to drop between the headliners. The staves shall be bolted tightly to the heads by four three-fourths inch bolts, and each bolt shall be provided with a lock nut, and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

(8) *The frame and driving mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The countershaft upon which the driving pinion is mounted shall not be less than $1\frac{5}{16}$ inches in diameter, with bearing not less than 6 inches in length. If a belt drive is used the pulley shall not be less than 18 inches in diameter and $6\frac{1}{2}$ inches in face. A belt at least 6 inches in width properly adjusted, to avoid unnecessary slipping, should be used.

(9) *The abrasive charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 inches in diameter and shall weigh approximately 7.5 pounds (3.40 kg.) each. Ten spheres of this size shall be used.

These shall be weighed separately after each 10 tests, and if the weight of any large sphere falls to 7 pounds (3.175 kg.) it shall be discarded and a new one substituted; provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller spheres shall be 1.875 inches in diameter and shall weigh approximately 0.95 pound (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 pounds as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole

1.75 inches in diameter, drilled in an iron plate one-fourth inch in thickness, or weigh less than 0.75 pound (0.34 kg.). Further, the small spheres shall be tested, by passing them over the above plate or by weighing, after every 10 tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres; provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective, it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon	Not under 2.50 per cent.
Graphitic carbon	Not over 0.25 per cent.
Silicon	Not over 1.00 per cent.
Manganese	Not over 0.50 per cent.
Phosphorus	Not over 0.25 per cent.
Sulphur	Not over 0.08 per cent.

For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user, before introducing into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

(10) *The brick charge.*—The number of bricks per test shall be 10 for all bricks of so-called "block-size," whose dimensions fall between 8 and 9 inches in length, 3 and $3\frac{3}{4}$ inches in breadth, and $3\frac{3}{4}$ and $4\frac{1}{4}$ inches in thickness.[6] No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

(11) *Speed and duration of revolution.*—The rattler shall be rotated at a uniform rate of not less than 29.5 nor more than 30.5 revolutions per minute, and 1,800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed 10 revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

(12) *The scales.*—The scales must have a capacity of not less than 300 pounds, and must be sensitive to 0.5 ounce, and must be tested by a standard test weight at intervals of not less than every 10 tests.

(13) *The results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick, any piece weighing less than 1 pound shall be rejected.

(14) *The records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made:

1. The name of the person, firm, or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street, or contract, which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were tested.

[6] Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

7. The drying treatment given before testing, if any.
8. The length, breadth, and thickness of the bricks.
9. The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
10. The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
11. The total weight of the shot charge after its last standardization.
12. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them right at the beginning of the test.
13. Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of stave liners.
14. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the indicator.
15. Certificate of the operator as to number of stops and starts made in each test.
16. The initial collective weight of the ten bricks composing the charge and their collective weight after rattling.
17. The loss calculated in percentage of the initial weight; and the calculation itself.
18. The number of broken bricks and remarks upon the portions which were included in the final weighing.
19. General remarks upon the test and any irregularities occurring in its execution.
20. The date upon which the test was made.
21. The location of the rattler, upon which the test was made, and name of the owner.
22. The certificate of the operator that the test was made under the specifications of the American Society for Testing Materials and that the record is a true record.
23. The signature of the operator or person responsible for the test.
24. The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicates, but the original record shall always be preserved intact and complete.

For the convenience of the public, the accompanying blank form, which provides space for the necessary data, is furnished and its use recommended.

Serial No. .....

Report of Standard Rattler Test of Paving Brick.

Identification data.

Name of the firm furnishing sample.....
Name of the firm manufacturing sample.....
Street or job which sample represents.....
Brands or marks on the brick.....
Quantity furnished..... Drying treatment.....
Date received..... Date tested.....
Length..... Breadth..... Thickness.....

Standardization data.

Weight of charge (after standardization).	Condition of lock nuts on staves.	Condition of staves.	Number and position of fresh stave liners.	Repairs (not any repairs affecting the condition of the barrel).
10 large spheres.....				
Small spheres.....				
Total.....				

Number of charges tested since last inspection.....

Running data.

	Time readings.			Revolution counter readings.	Running notes, stops, etc.
	Hours.	Minutes.	Seconds.		
Beginning of test.....					
Final reading.....					

Weights and calculations.

		Percentage loss (the calculation must appear).
Initial weight of 10 bricks.....		
Final weight of same.....		
Loss of weight.....		

Number of broken bricks and remarks on same.....

I certify that the foregoing test was made under the specifications of the American Society for Testing Materials, and is a true record.

(Signature of tester).....

Date.....
Location of laboratory.....

ACCEPTANCE AND REJECTION OF MATERIAL.

(15) *Basis of acceptance or rejection.*—Paving bricks shall not be judged for acceptance or rejection by the results of individual tests, but by the average of no less than five tests. Where a lot of bricks fail to meet the required average, it shall be optional with the buyer whether the bricks shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in section 16.

(16) *Range of fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variations in the bricks and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than 2 per cent, then the portion of the lot represented by that test shall be at once resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than 2 per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick two or more tests exceed the permissible maximum, then the buyer may at his option reject the entire lot, even though the average of all the tests executed may be within the required limits.

(17) *Fixing of standards.*—The percentage of loss which may be taken as the standard will not be fixed in these specifications, and shall remain within the province of the contracting parties. For the information of the public, the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	General average loss.	Maximum permissible loss.
	Per cent.	*Per cent.*
For bricks suitable for heavy traffic	22	24
For bricks suitable for medium traffic	24	26
For bricks suitable for light traffic	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer and should be governed by the kind and amount of traffic to be carried and the quality of paving bricks available.

(18) *Culling and retesting.*—Where, under sections 15 and 16, a lot or portion of a lot of bricks is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

(19) *Payment of cost of testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also section 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it shall be paid by the seller, whether the material is finally accepted or rejected.

II. VISUAL INSPECTION.

It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use and prior to or during laying, to cull out and reject upon the following grounds:

(20) All bricks which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

(21) All bricks which are cracked in such a degree as to produce defects such as are defined in section 20, either from shocks received in shipment and handling or from defective conditions of manufacture, especially in drying, burning, or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

(22) All bricks which are so offsize, or so misshapen, bent, twisted, or kiln marked, that they will not form a proper surface as defined by the paving specifications, or align with other bricks without making joints other than those permitted in the paving specifications.

(23) All bricks which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in section 2, and if in either or both tests the bricks fall beyond the maximum rattler losses permitted under the specifications, then all bricks having the same objectionable appearance may be excluded, and the seller shall pay for the cost of the test. But if under such procedure the bricks which have been tested as objectionable shall pass the rattler test, both tests falling within the permitted maximum, then the buyer can not exclude the class of material represented by this test and he shall pay for the cost of the test.

(24) All bricks which differ so markedly in color from the type or average of the shipment as to make the resultant pavement checkered or disagreeably mottled in appearance. This section shall not be held to apply to the normal variations in color which may occur in the product of one plant among bricks, which will meet the rattler test as referred to in sections 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

Absorption.[7]—The absorption test shall be made on five rattled brick, which shall be immersed in water for 48 hours. The absorption shall be expressed in per cent of the weight of the brick before immersion.

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[7] Not a part of the A. S. T. M. standard method.

TESTS FOR BITUMINOUS ROAD MATERIALS.

19. DETERMINATION OF SPECIFIC GRAVITY OF BITUMINOUS MATERIALS.

A. HYDROMETER METHOD (USED FOR THIN FLUID BITUMENS).

The specific gravity of thin fluid bituminous road materials is determined at 25° C. as compared with water at that temperature. This may be done with the above-mentioned apparatus by first pouring a sufficient quantity of the material into the tin cup, which is then placed in the large dish containing cold or warm water as occasion may require. The material in the cup should be stirred with the thermometer until

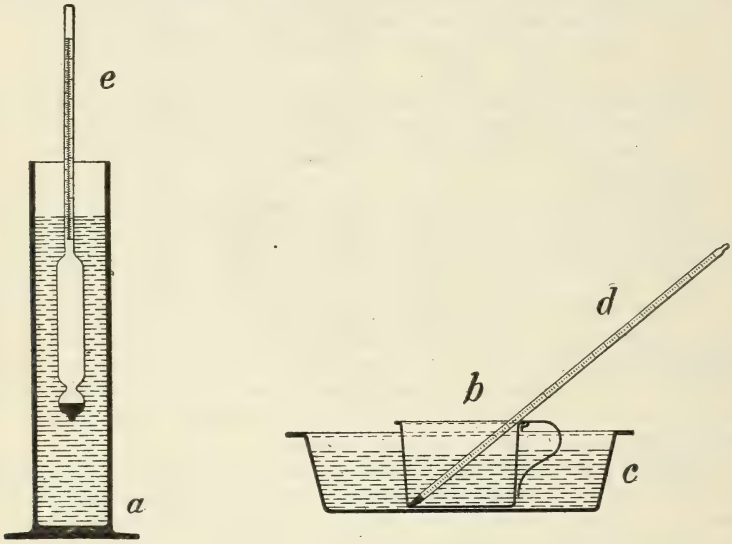


FIG. 15.—Hydrometer method of determining specific gravity.

it is brought to a temperature of 25° C., after which it should be immediately poured into the hydrometer jar and its gravity determined by means of the proper hydrometer. In case the hydrometer sinks slowly, owing to the viscosity of the material, it should be given sufficient time to come to a definite resting point, and this point should be checked by raising the hydrometer and allowing it to sink a second time. The hydrometer should never be pushed below the point at which it naturally comes to rest until the last reading has been made. It may then be pushed below the reading for a distance of three or four of the small divisions on the scale, whereupon it should immediately begin to rise. If it fails to do so, the material is too viscous for the hydrometer method, and the pycnometer method should be employed.

The direct specific gravity reading obtained by the foregoing method is based upon water at 15.5° C. taken as unity. For all practical purposes this reading may be corrected to water at 25° C., considered as unity, by multiplying it by 1.002. Thus: Specific gravity 25° C./25° C.=specific gravity 25° C./15.5° C.$\times$1.002.

B. PYCNOMETER METHOD (USED FOR VISCOUS FLUID AND SEMISOLID BITUMENS AND EMULSIONS).

The inconvenience and difficulty of employing the ordinary narrow neck pycnometer when determining the specific gravity of viscous fluid and semisolid bitumens has led to the use of a special form shown in figure 16.

U. S. DEPARTMENT OF AGRICULTURE BULLETIN NO. 949.

Standard and Tentative Methods of Sampling and Testing Highway Materials.

Errata.

P. 37. Change the formula for specific gravity to read

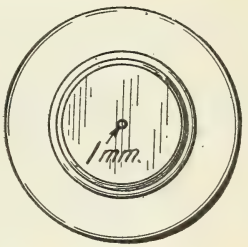
$$\text{Specific gravity } 25^\circ\text{C.}/25^\circ\text{C.} = \frac{c-a}{(b-a)-(d-c)}$$

This pycnometer consists of a conical or Erlenmeyer-shaped flask about 4.5 cm. high, 4.0 cm. diameter at bottom, and 2.5 cm. diameter at the mouth. It is carefully ground to receive an accurately fitting solid glass stopper with a hole about 1 mm. bore in place of the usual capillary opening. The lower surface of this stopper is made concave to allow air bubbles to escape through the bore. The depth of the cup-shaped depression is 4.8 mm. at the center. The flask has a capacity of about 25 c. c. and weighs when empty about 25 grams. Its principal advantages are (1) that any desired amount of bitumen may be poured in without touching the sides above the desired level; (2) it is easily cleaned; (3) on account of the 1.0 mm. bore the stopper can be easily inserted when the flask is filled with a viscous oil.

When working with semisolid bitumens which are too soft to be broken and handled in fragments, the following method of determining their specific gravity is employed:

The clean, dry pycnometer is first weighed empty, and this weight is called *a*. It is then filled in the usual manner with freshly distilled water at 25° C., and the weight is again taken and called *b*. A small amount of the bitumen should be placed in the spoon and brought to a fluid condition by the gentle application of heat, with care that no loss by evaporation occurs. When sufficiently fluid, enough is poured into the dry pycnometer, which may also be warmed, to fill it about half full without allowing the material to touch the sides of the tube above the desired level. The flask and contents are then allowed to cool to room temperature, after which the tube is carefully weighed with the stopper. This weight is called *c*. Distilled water, at 25° C., is then poured in until the pycnometer is full. After this the stopper is inserted, and the whole cooled to 25° C. by a 30-minute immersion in a beaker of distilled water maintained at this temperature. All surplus moisture is then removed with a soft cloth, and the pycnometer and contents are weighed. This weight is called *d*. From the weights obtained the specific gravity of the bitumen may be readily calculated by the following formula:

$$\text{Specific gravity } 25°\text{ C.}/25°\text{ C.} = \frac{(b-a)-(d-c)}{c-a}$$



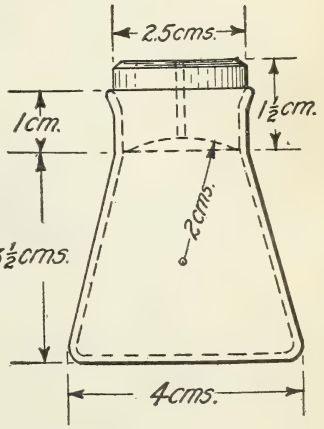


FIG. 16.—Hubbard-Carmick pycnometer. (Dimensions only approximate.)

Both *a* and *b* are constants and need be determined but once. It is therefore necessary to make but two weighings for each determination after the first. Results obtained according to the method given above are accurate to within 2 units in the third decimal place, while the open-tube method is accurate to the second decimal place only.

The specific gravity of fluid bitumens may be determined in the ordinary manner with this pycnometer by completely filling it with the material and dividing the weight of the bitumen thus obtained by that of the same volume of water.

The pycnometer may be readily cleaned by placing it in a hot-air bath until the bitumen is sufficiently fluid to pour. As much is drained out as possible and the interior swabbed with a piece of cotton waste. It is then rinsed clean with a little carbon disulphide, and after drying is again ready for use.

C. DISPLACEMENT METHOD (USED FOR HARD SOLID BITUMENS).

For materials which are hard enough to be broken and handled in fragments at room temperature, the following method will prove convenient. A small fragment of the bitumen (about 1 c. c.) is suspended by means of a silk thread from the hook on one of the pan supports, about 1½ inches above the pan, and weighed. This weight is called *a*. It is then weighed immersed in water at 25° C., as shown in figure 17, and this weight is called *b*. The specific gravity may then be calculated by means of the following formula:

$$\text{Specific gravity} = \frac{a}{a-b}$$

20. DETERMINATION OF BITUMEN SOLUBLE IN CARBON DISULPHIDE.

This test consists in dissolving the bitumen in carbon disulphide and recovering any insoluble matter by filtering the solution through an asbestos felt. The form of Gooch crucible best adapted for the determination is 4.4 cm. wide at the top, tapering to 3.6 cm. at the bottom, and is 2.5 cm. deep.

For preparing the felt the necessary apparatus is arranged as shown in figure 18, in which *a* is the filtering flask, *b* a rubber stopper, *c* the filter tube, and *d* a section

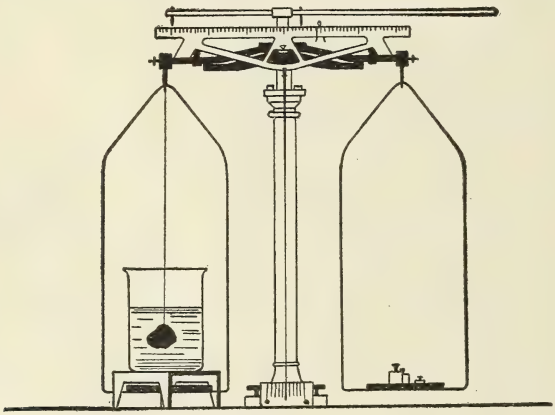


FIG. 17.—Displacement method of determining specific gravity.

of rubber tubing which tightly clasps the Gooch crucible, *e*. The asbestos is cut with scissors into pieces not exceeding 1 cm. in length, after which it is shaken up with just sufficient water to pour easily. The crucible is filled with the suspended asbestos, which is allowed to settle for a few moments. A light suction is then applied to draw off all the water and leave a firm mat of asbestos in the crucible. More of the suspended material is added, and the operation is repeated until the felt is so dense that it scarcely transmits light when held so that the bottom of the crucible is between the eye and the source of light. The felt should then be washed several times with water and drawn firmly against the bottom of the crucible by an increased suction. The crucible is removed to a drying oven for a few minutes, after which it is ignited at red heat over a Bunsen burner, cooled in a desiccator, and weighed.

From 1 to 2 grams of bitumen or about 10 grams of an asphalt topping or rock asphalt is now placed in the Erlenmeyer flask, which has been previously weighed, and the accurate weight of the sample is obtained. One hundred cubic centimeters of chemically pure carbon disulphide is poured into the flask in small portions, with continual agitation, until all lumps disappear and nothing adheres to the bottom. The flask is then corked and set aside for 15 minutes.

After being weighed, the Gooch crucible containing the felt is set up over the dry-pressure flask, as shown in figure 18, and the solution of bitumen in carbon disulphide is decanted through the felt without suction by gradually tilting the flask, with care not to stir up any precipitate that may have settled out. At the first sign of any sediment coming out, the decantation is stopped and the filter allowed to drain. A small amount of carbon disulphide is then washed down the sides of the flask, after which the precipitate is brought upon the felt and the flask scrubbed, if necessary, with a feather or "policeman" to remove all adhering material. The contents of the crucible are washed with carbon disulphide, until the washings run colorless. Suction is then applied until there is practically no odor of carbon disulphide in the crucible, after which the outside of the crucible is cleaned with a cloth moistened with a small amount of the solvent. The crucible and contents are dried in the hot-air oven at 100° C. for about 20 minutes, cooled in a desiccator, and weighed. If any appreciable amount of insoluble matter adheres to the flask, it should also be dried and weighed, and any increase over the original weight of the flask should be added to the weight of insoluble matter in the crucible. The total weight of insoluble material may include both organic and mineral matter. The former, if present, is burned off by ignition at a red heat until no incandescent particles remain, thus leaving the mineral matter or ash, which can be weighed on cooling. The difference between the total weight of material insoluble in carbon disulphide and the weight of substance taken equals the total bitumen, and the percentage weights are calculated and reported as total bitumen, and organic and inorganic matter insoluble, on the basis of the weight of material, taken for analysis.

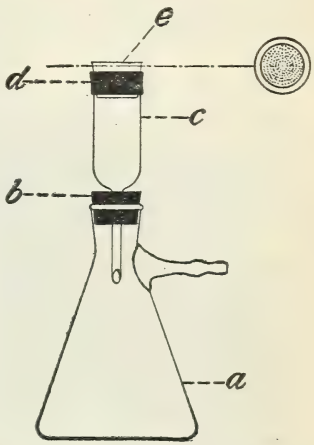


FIG. 18.—Apparatus for determining soluble bitumen.

This method is quite satisfactory for straight oil and tar products, but where certain natural asphalts are present it will be found practically impossible to retain all of the finely divided mineral matter on an asbestos felt. It is, therefore, generally more accurate to obtain the result for total mineral matter by direct ignition of a 1-gram sample in a platinum crucible or to use the result for ash obtained in the fixed carbon test. The total bitumen is then determined by deducting from 100 per cent the sum of the percentages of total mineral matter and organic matter insoluble. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash from the fixed carbon determination with a few drops of ammonium carbonate solution, drying at 100° C., then heating for a few minutes at a dull red heat, cooling, and weighing again.

When difficulty in filtering is experienced—for instance, when Trinidad asphalt is present in any amount—a period of longer subsidence than 15 minutes is necessary, and the following method proposed by the Committee on Standard Tests for Road Materials of the American Society for Testing Materials is recommended:

From 2 to 15 grams (depending on the richness in bitumen of the substance) is weighed into a 150-cubic centimeter Erlenmeyer flask, the tare of which has been previously ascertained, and treated with 100 c. c. of carbon disulphide. The flask is then loosely corked and shaken from time to time until practically all large particles of the material have been broken up, when it is set aside and not disturbed for 48 hours. The solution is then decanted off into a similar flask that has been previously weighed, as much of the solvent being poured off as possible without disturbing the

residue. The first flask is again treated with fresh carbon disulphide and shaken as before, when it is put away with the second flask and not disturbed for 48 hours.

At the end of this time the contents of the two flasks are carefully decanted off upon a weighed Gooch crucible fitted with an asbestos filter, the contents of the second flask being passed through the filter first. The asbestos filter shall be made of ignited long-fiber amphibole, packed in the bottom of a Gooch crucible to the depth of not over one-eighth of an inch. After passing the contents of both flasks through the filter, the two residues are shaken with more fresh carbon disulphide and set aside for 24 hours without disturbing, or until it is seen that a good subsidation has taken place, when the solvent is again decanted off upon the filter. This washing is continued until the filtrate or washings are practically colorless,

The crucible and both flasks are then dried at 125° C. and weighed. The filtrate containing the bitumen is evaporated, the bituminous residue burned, and the weight of the ash thus obtained added to that of the residue in the two flasks and the crucible. The sum of these weights deducted from the weight of substance taken gives the weight of bitumen extracted.

21. DETERMINATION OF BITUMEN INSOLUBLE IN CARBON TETRACHLORIDE.

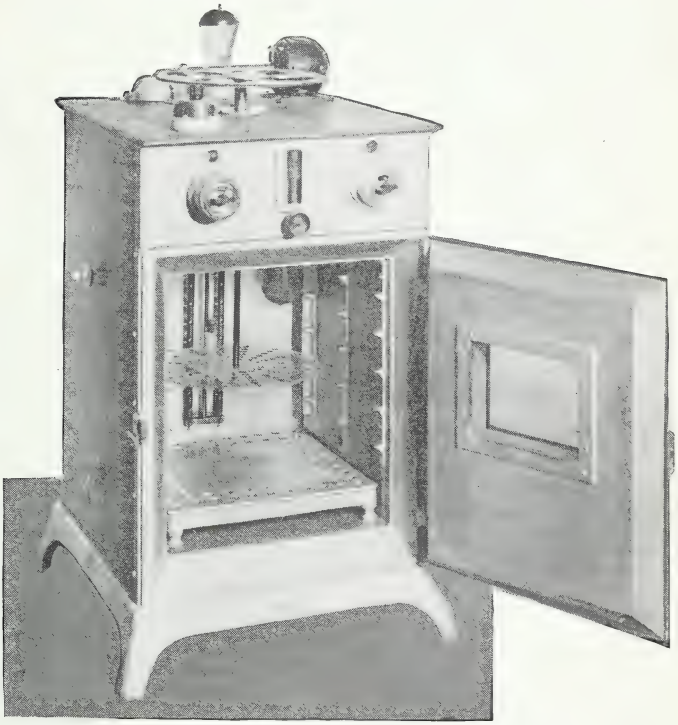
This determination is conducted in exactly the same manner as described under "Determination of bitumen soluble in carbon disulphide," using 100 c. c. of chemically pure carbon tetrachloride as a solvent in place of carbon disulphide.

The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100, as described under "Determination of bitumen insoluble in paraffin naphtha."

22. DETERMINATION OF BITUMEN INSOLUBLE IN PARAFFIN NAPHTHA.

This determination is made in the same general manner as the total bitumen determination, except that 100 c. c. of 86° to 88° B. paraffin naphtha, at least 85 per cent distilling between 35° C. and 65° C., is employed as a solvent instead of carbon disulphide. Considerable difficulty is sometimes experienced in breaking up some of the heavy semisolid bitumens; the surface of the material is attacked, but it is necessary to remove some of the insoluble matter in order to expose fresh material to the action of the solvent. It is, therefore, advisable to heat the sample after it is weighed, allowing it to cool in a thin layer around the lower part of the flask. If difficulty is still experienced in dissolving the material, a rounded glass rod will be found convenient for breaking up the undissolved particles. Not more than one-half of the total amount of naphtha required should be used until the sample is entirely broken up. The balance of the 100 c. c. is then added, and the flask is twirled a moment in order to mix the contents thoroughly, after which it is corked and set aside for 30 minutes.

In making the filtration the utmost care should be exercised to avoid stirring up any of the precipitate, in order that the filter may not be clogged and that the first decantation may be as complete as possible. The sides of the flask should then be quickly washed down with naphtha and, when the crucible has drained, the bulk of insoluble matter is brought upon the felt. Suction may be applied when the filtration by gravity almost ceases, but should be used sparingly, as it tends to clog the filter by packing the precipitate too tightly. The material on the felt should never be allowed to run entirely dry until the washing is completed, as shown by the colorless filtrate. When considerable insoluble matter adheres to the flask no attempt should be made to remove it completely. In such cases the adhering material is merely washed until free from soluble matter, and the flask is dried with the crucible at 100° C.



ELECTRIC OVEN FOR VOLATILIZATION TEST.

for about one hour, after which it is cooled and weighed. The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100.

The difference between the material insoluble in carbon disulphide and in the naphtha is the bitumen insoluble in the latter. Thus, if in a certain instance it is found that the material insoluble in carbon disulphide amounts to 1 per cent and that 10.9 per cent is insoluble in naphtha, the percentage of bitumen insoluble would be calculated as follows:

$$\frac{\text{Bitumen insoluble in naphtha}}{\text{Total bitumen}} = \frac{10.9-1}{100-1} = \frac{9.9}{99} = 10 \text{ per cent.}$$

23. VOLATILIZATION TEST.

An oven is used that will give a uniform temperature throughout all parts where samples are placed. A gas oven of the type shown in figure 19 or an electric oven of proper design (see Pl. I) may be used. The bulb of one of the thermometers is immersed in a sample of some fluid nonvolatile bitumen, while the other is kept in air at the same level. The first thermometer serves to show the temperature of the samples during the test, while the latter gives prompt warning of any sudden changes in temperature due to irregularities in the heat.

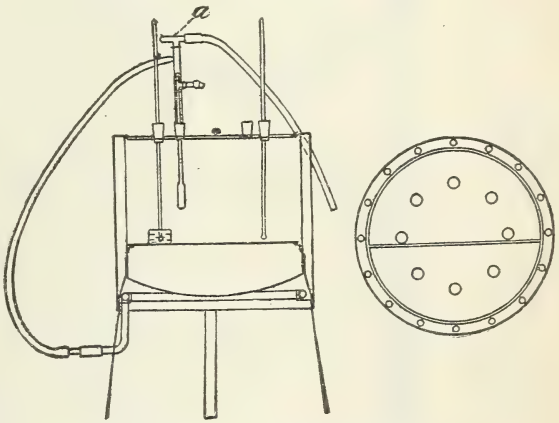


FIG. 19.—New York Testing Laboratory oven.

Before making the test the interior of the oven should show a temperature of 163° C. as registered by the thermometer in air. A tin box 5½ cm. in diameter and 3½ cm. deep (American Can Co., gill type, deep pattern ointment box) is accurately weighed after carefully wiping with a towel to remove any grease or dirt. About 50 grams of the material to be tested is then placed in the box. The material may then be weighed on a rough balance, if one is at hand, after which the accurate weight, which should not vary more than 0.2 gram from the specified amount, is obtained. It may be necessary to warm some of the material in order to handle it conveniently, after which it must be allowed to cool before determining the accurate weight.

The sample should now be placed in the oven, where it is allowed to remain for a period of five hours, during which time the temperature as shown by the thermometer in bitumen should not vary at any time more than 2° C. The sample is then removed from the oven, allowed to cool, and reweighed. From the difference between this weight and the total weight before heating the percentage of loss on the amount of material taken is calculated.

The general appearance of the residue should be noted, especially with regard to any changes which the material may have undergone. Some relative idea of the amount of hardening which has taken place may be obtained from the results of a float or penetration test made on the residue, as compared with the results of the same test on the original sample. It is also frequently desirable to make the specific gravity and other tests on the residue for the purpose of identifying or ascertaining the character of the base used in the preparation of cut-back products. Before any tests are made on the residue, it should be melted and thoroughly stirred while cooling.

Highly volatile and nonvolatile materials should not be subjected to this test at the same time in the same oven owing to a tendency on the part of the latter to absorb some of the volatile products of the former.

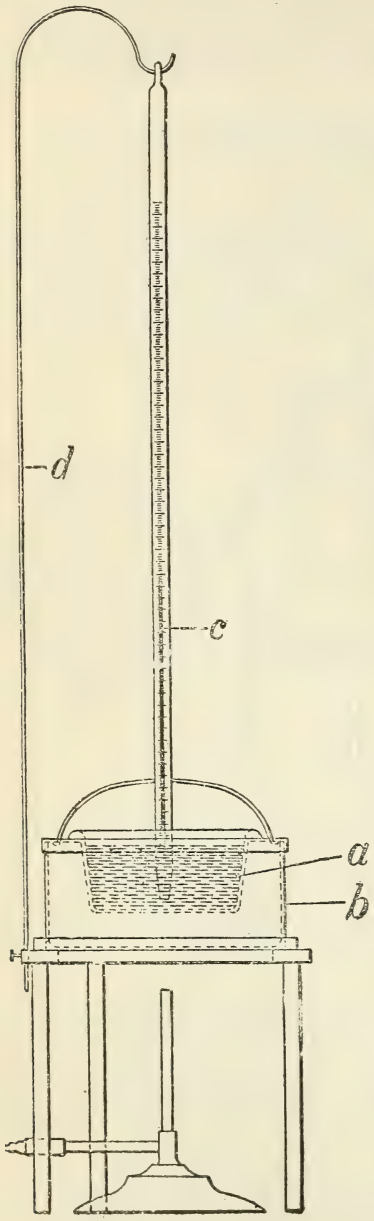


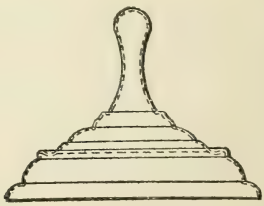
FIG. 20.—Open-cup oil tester.

24. FLASH AND BURNING POINT TESTS.

The open-cup oil tester consists of a brass oil cup, *a*, (Fig. 20) of about 100 c. c. capacity. The outer vessel, *b*, serves as an air jacket. No glass cover is used in the open-cup method. A suitable thermometer, *c*, is suspended from the wire support, *d*, directly over the center of the cup so that its bulb is entirely covered with oil but does not touch the bottom of the cup. The testing flame is obtained from a jet of gas passed through a piece of glass tubing, and should be about 5 millimeters in length.

The test is made by first filling the oil cup with the material under examination to within about 5 m. m. of the top. The Bunsen flame is then applied in such a manner that the temperature of the material in the cup is raised at the rate of 5° C. per minute. From time to time the testing flame is brought almost in contact with the surface of the oil. A distinct flicker or flash over the entire surface of the oil shows that the flash point is reached and the temperature at this point is taken. It will usually be found that the flash point as determined by the open-cup method is somewhat higher than by the closed-cup method, for the same material.

The burning point of the material is obtained by continuing the test and noting that temperature at which it ignites and burns. The flame should then be extinguished by means of a metal cover supplied with the instrument.



25. FLOAT TEST FOR CONSISTENCY.

The float apparatus consists of two parts (see fig. 21), an aluminum float or saucer, *a*, and a conical brass collar, *b*. The two parts are made separately, so that one float may be used with a number of brass collars.

In making the test the brass collar is placed with the small end down on the brass plate, which has been previously amalgamated with mercury by first rubbing it with a dilute solution of mercuric chloride or nitrate and then with mercury. A small quantity of the material to be tested is heated in the metal spoon until quite fluid, with care that it suffers no appreciable loss by volatilization and that it is kept free from air bubbles. It is then poured into the collar in a thin stream until slightly more than level with the top. The surplus may be removed, after the material has cooled to room temperature, by means of a spatula or steel knife which has been slightly heated. The collar and plate are then placed in one of the tin cups containing ice

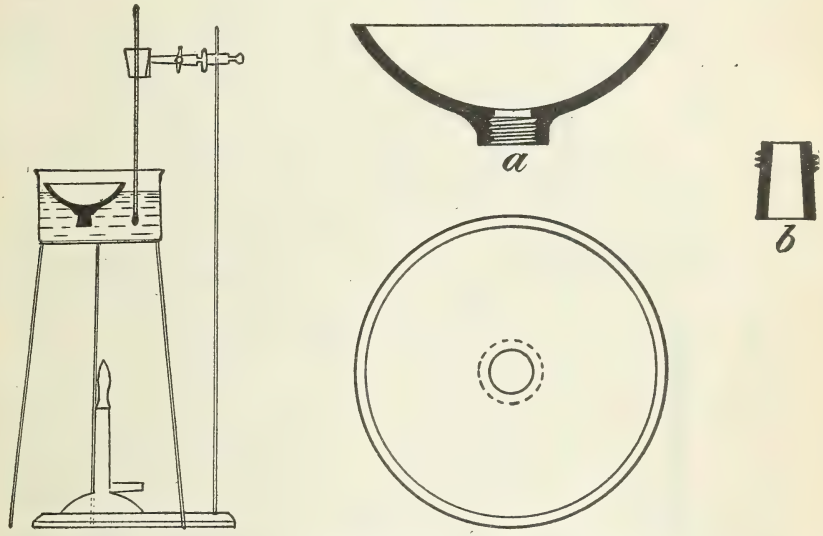


FIG. 21.—New York Testing Laboratory float apparatus.

water maintained at 5° C., and left in this bath for at least 15 minutes. Meanwhile the other cup is filled about three-fourths full of water and placed on the tripod, and the water is heated to any desired temperature at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than one-half a degree centigrade from the temperature selected. After the material to be tested has been kept in the ice water for at least 15 minutes, the collar with its contents is removed from the plate and screwed into the aluminum float, which is then immediately floated in the warmed bath. As the plug of bituminous material becomes warm and fluid, it is gradually forced upward and out of the collar, until water gains entrance to the saucer and causes it to sink.

The time in seconds between placing the apparatus on the water and when the water breaks through the bitumen is determined by means of a stop watch and is taken as a measure of the consistency of the material under examination.

26. FIXED CARBON DETERMINATION.

This determination is made in accordance with the method described for coal in the Journal of the American Chemical Society, 1899, volume 21, page 1116. One gram of the material is placed in a platinum crucible weighing from 20 to 30 grams and having a tightly fitting cover. It is then heated for seven minutes over the full flame of a Bunsen burner, as shown in figure 22. The crucible should be supported on a platinum triangle with the bottom from 6 to 8 cm. above the top of the burner. The flame should be fully 20 cm. high when burning freely, and the determination should be made in a place free from drafts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon, excepting in the case of some of the more fluid bitumens, when the under surface of the cover may be quite clean.

The crucible is removed to a desiccator and when cool is weighed, after which the cover is removed, and the crucible is placed in an inclined position over the Bunsen burner and ignited until nothing but ash remains. Any carbon deposited on the cover is also burned off. The weight of ash remaining is deducted from the weight of the residue after the first ignition of the sample. This gives the weight of the so-called fixed or residual carbon, which is calculated on a basis of the total weight of the sample, exclusive of mineral matter. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash with a few drops of ammonium carbonate solution, drying at 100° C. then heating for a few minutes at a dull red heat, cooling and weighing.

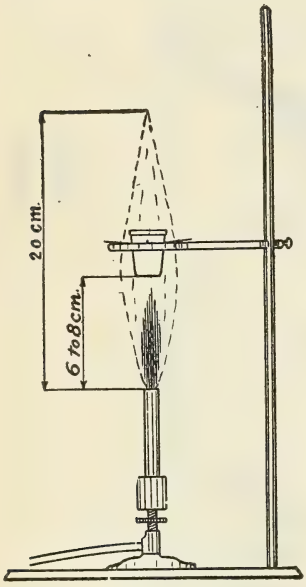


FIG. 22.—Apparatus for determining fixed carbon.

An excellent form of crucible for this test has a cover with a flange 4 mm. wide, fitting tightly over the outside of the crucible, and weighs complete about 25 grams. Owing to sudden expansion in burning some of the more fluid bitumens, it is well to hold the cover down with the end of the tongs until the most volatile products have burned off.

Some products, particularly those derived from Mexican petroleum, show a tendency to suddenly expand and foam over the sides of the crucible in making this determination, and no method of obviating this trouble without vitiating the result has thus far been forthcoming. Recent experiments in the laboratory of the Bureau of Public Roads indicate that the difficulty may be overcome by placing a small piece of platinum gauze over the sample and about midway of the crucible. The gauze should be so cut or bent as to touch the sides of the crucible at all points, and is of course weighed in place in the crucible before and after ignition.

27. SPECIFIC VISCOSITY DETERMINATION.

The viscosity of fluid bituminous road materials may be determined at any suitable temperature by means of the Engler viscosimeter. This apparatus is shown in figure 23, and may be described as follows: *a*, is a brass vessel for holding the material to be tested, and may be closed by the cover, *b*. To the conical bottom of *a* is fitted a conical outflow tube, *c*, exactly 20 mm. long, with a diameter at the top of 2.9 mm. and at the bottom of 2.8 mm. This tube can be closed and opened by the pointed hardwood stopper, *d*. Pointed metal projections are placed on the inside of *a* at

equal distances from the bottom and serve for measuring the charge of material, which is 240 c. c. The thermometer *e* is used to ascertain the temperature of the material to be tested. The vessel *a* is surrounded by a brass jacket, *f*, which holds the material used as a heating bath, either water or cottonseed oil, according to the temperature at which the test is to be made. A tripod, *g*, serves as a support for the apparatus and also carries a ring burner *h*, by means of which the bath is directly heated. The measuring cylinder of 100 c. c. capacity, which is sufficiently accurate for work with road materials, is placed directly under the outflow tube.

As all viscosity determinations should be compared with that of water at 25° C., the apparatus should be previously calibrated as follows: The cup and outlet tube should first be scrupulously cleaned. A piece of soft tissue paper is convenient for cleaning the latter. The stopper is then inserted in the tube and the cup filled with water at 25° C. to the top of the projections. The measuring cylinder should be placed directly under the outflow tube so that the material, upon flowing out, will not touch the sides, and the stopper may then be removed. The time required both for 50 and 100 c. c. to run out should be ascertained by means of a stop watch, and the results so obtained should be checked a number of times. The time required for 50 c. c. of water should be about 11 seconds and for 100 c. c. about 22.8 seconds.

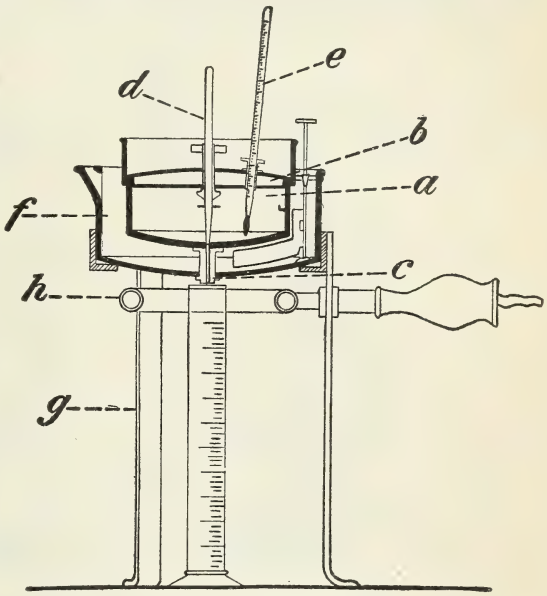


FIG. 23.—Engler viscosimeter.

Bituminous road materials are tested in the same manner as water, and the temperature at which the test is made is controlled by the bath. The material should be brought to the desired temperature and maintained there for at least three minutes before making the test. The results are expressed as specific viscosity compared with water at 25° C., as follows:

$$\text{Specific viscosity at A° C.} = \frac{\text{seconds for passage of given volume at A°C.}}{\text{seconds for passage of same volume of water at 25° C.}}$$

28. DETERMINATION OF PERCENTAGE OF RESIDUE OF DESIRED PENETRATION.

Fifty grams of the oil are placed in a 3-ounce deep, seamless tin box; the box is placed in a sand bath and heated over a Bunsen burner. A thermometer is suspended in the oil, the bulb not touching the bottom of the box. The temperature of the oil is kept at from 249° C. (480° F.) to 260° C. (500° F.), and the oil is stirred from time to time with the thermometer to prevent overheating in any part. Depending upon the nature of the oil, as usually indicated by its flash, consistency at 25° C. (77° F.) and specific gravity, the operator can with experience tell about what percentage it will be necessary to evaporate before cooling and taking a penetration of the residue.

It is sometimes necessary to make several trials before the desired result is obtained. When the required penetration is reached, the residue left from evaporation is weighed and its per cent of the original sample taken is computed.

29. TEST FOR PENETRATION OF BITUMINOUS MATERIALS.

(A. S. T. M. Standard Method, Serial Designation: D 5–16.)

I. DEFINITION.

(1) Penetration is defined as the consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time, and temperature. Where the conditions of test are not specifically mentioned, the load, time, and temperature are understood to be 100 grams, 5 seconds, 25° C (77° F.), respectively, and the units of penetration to indicate hundredths of a centimeter.

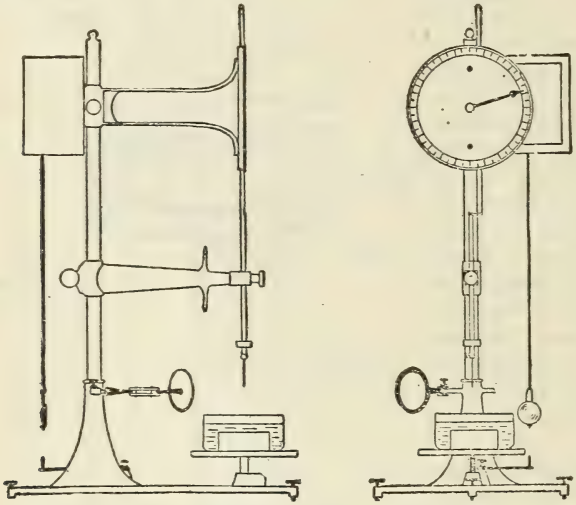


FIG. 24.—New York Testing Laboratory penetrometer.

II. APPARATUS.

(2) The container for holding the material to be tested shall be a flat-bottom, cylindrical dish, 55 mm. ($2\frac{3}{16}$ inches) in diameter and 35 mm. ($1\frac{3}{8}$ inches) deep.[8] (See figs. 24 and 25.)

(3) The needle[9] for this test shall be of cylindrical steel rod 50.8 mm. (2 inches) long and having a diameter of 1.016 mm. (0.04 inch) and turned on one end to a sharp point having a taper of 6.35 mm. (one-fourth inch).

(4) The water bath shall be maintained at a temperature not varying more than 0.1° C. from 25° C. (77° F.) The volume of water shall be not less than 10 liters and the sample shall be immersed to a depth of not less than 10 cm. (4 inches) and shall be supported on a perforated shelf not less than 5 cm. (2 inches) from the bottom of the bath.

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[8] This requirement is fulfilled by the American Can Co.'s gill style ointment box, deep pattern, 3-ounce capacity.

[9] It is recommended that the Roberts No. 2 parabola needle be used until such a time as Committee D-4 of the American Society for Testing Materials are in a position to make a recommendation relative to a type of needle which may generally be obtained.

(5) Any apparatus which will allow the needle to penetrate without appreciable friction, and which is accurately calibrated to yield results in accordance with the definition of penetration will be acceptable.

(6) The transfer dish for container shall be a small dish or tray of such capacity as will insure complete immersion of the container during the test. It shall be provided with some means which will insure a firm bearing and prevent rocking of the container.

III. PREPARATION OF SAMPLE.

(7) The sample shall be completely melted at the lowest possible temperature and stirred thoroughly until it is homogeneous and free from air bubbles. It shall then be poured into the sample container to a depth of not less than 15 mm. ($\frac{5}{8}$ inch). The sample shall be protected from dust and allowed to cool in an atmosphere not lower than 18° C. (65° F.) for one hour. It shall then be placed in the water bath along with the transfer dish and allowed to remain one hour.

IV. TESTING.

(8) (*a*) In making the test the sample shall be placed in the transfer dish filled with water from the water bath of sufficient depth to completely cover the container.

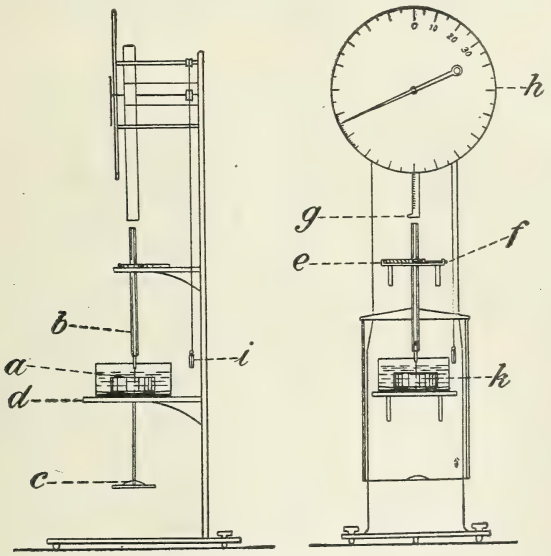

FIG. 25.—Dow penetration machine.

The transfer dish containing the sample shall then be placed upon the stand of the penetration machine. The needle, loaded with specified weight, shall be adjusted to make contact with the surface of the sample. This may be accomplished by making contact of the actual needle point with its image reflected by the surface of the sample from a properly placed source of light. Either the reading of the dial shall then be noted or the needle brought to zero. The needle is then released for the specified period of time, after which the penetration machine is adjusted to measure the distance penetrated.

At least three tests shall be made at points on the surface of the sample not less than 1 cm. ($\frac{3}{8}$ inch) from the side of the container and not less than 1 cm. ($\frac{3}{8}$ inch) apart. After each test the sample and transfer dish shall be returned to the water bath and the needle shall be carefully wiped toward its point with a clean, dry cloth to remove

all adhering bitumen. The reported penetration shall be the average of at least three tests whose values shall not differ more than four points between maximum and minimum.

(*b*) When desirable to vary the temperature, time, and weight, and in order to provide for a uniform method of reporting results when variations are made, the samples shall be melted and cooled in air as above directed. They shall then be immersed in water or brine, as the case may require, for one hour at the temperature desired. The following combinations are suggested:

At 0° C. (32° F.), 200-gram weight, 60 seconds.
At 46.1° C. (115° F.), 50-gram weight, 5 seconds.

30. DETERMINATION OF DUCTILITY OF BITUMINOUS MATERIALS.

(Method described in Trans. A. S. C. E., vol. 82, 1918, p. 1460.)

A briquette of the material to be tested shall be formed by pouring the molten material into a briquette mold. The dimensions of the briquette shall be 1 cm. (0.394 inch) in thickness throughout its entire length; distance between the clips or end pieces, 3 cm. (1.181 inches); width of asphalt cement section at mouth of clips, 2 cm. (0.787 inch); width at minimum cross section, half way between clips, 1 cm. (0.394 inch). The centerpieces are removable, the briquette mold being held together during molding with a clamp or wire.

The molding of the briquette shall be done as follows: The two center sections shall be well amalgamated to prevent the asphalt cement from adhering to them, and the briquette mold shall then be placed on a freshly amalgamated brass plate. The asphalt cement to be tested shall be poured into the mold while in a molten state, a slight excess being added to allow for shrinkage on cooling. When the asphalt cement in the mold is nearly cool, the briquette shall be cut off level, with a warm knife or spatula. When it is thoroughly cooled to the temperature at which it is desired to make the test, the clamp and the two sidepieces are removed, leaving the briquette of asphalt cement held at each end by the ends of the mold, which now play the part of clips. The briquette shall be kept in water for 30 minutes at 4° C. (39° F.) or 25° C. (77° F.) before testing, dependent on the temperature at which the ductility is desired. The briquette with the clips attached shall then be placed in a "ductility test machine" (fig. 26) filled with water at one of the above temperatures to a sufficient height to cover the briquette not less than 50 mm. (1.969 inches). This machine consists of a rectangular water-tight box, having a movable block working on a worm gear from left to right. The left clip is held rigid by placing its ring over a short metal peg provided for this purpose; the right clip is placed over a similar rigid peg on the movable block. The movable block is provided with a pointer which moves along a centimeter scale. Before starting the test, the centimeter scale is adjusted to the pointer at zero. Power is then applied by the worm-gear pulling from left to right at the uniform rate of 5 cm. (1.969 inches) per minute.

The distance, in centimeters, registered by the pointer on the scale at the time of rupture of the thread of asphalt cement shall be taken as the ductility of the asphalt cement.

31. STANDARD METHOD FOR THE DISTILLATION OF TAR AND TAR PRODUCTS.

(A. S. T. M. Standard Method, Serial Designation: D 20-18.)

(1) The sample as received shall be thoroughly stirred and agitated, warming, if necessary, to insure a complete mixture before the portion for analysis is removed.

(2) If the presence of water is suspected or known the material shall be dehydrated before distillation. About 500 c. c. of the material are placed in an 800-c. c. copper still provided with a distilling head connected with a water-cooled condenser (see

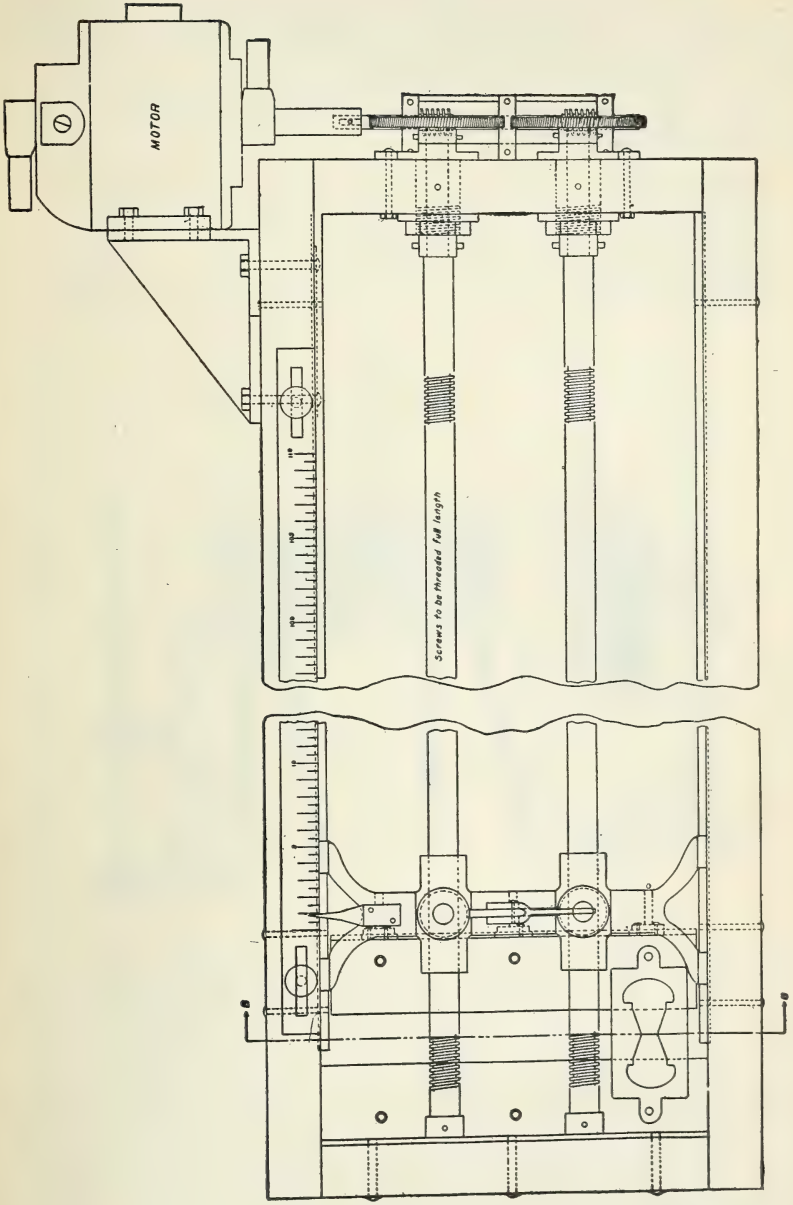

FIG. 26.—Machine for ductility test.

fig. 27). A ring burner is used, starting with a small flame at the top of the still and gradually lowering it, if necessary, until all the water has been driven off. The distillate is collected in a 200-c. c. separatory funnel with the tube cut off close to the stopcock. When all the water has been driven over and the distillate has settled out the water is drawn off and the oils returned to the residue in the still. The contents of the still shall have cooled to below 100° C. before the oils are returned, and they shall be well stirred and mixed with the residue.

(3) The apparatus shall consist of the following standard parts (see fig. 28):

(*a*) *Flask.*—The distillation flask shall be a 250-c. c. Engler distilling flask, having the following dimensions:

Diameter of bulb	8.0 cm.
Length of neck	15.0 cm.
Diameter of neck	1.7 cm.
Surface of material to lower side of tubulature	11.0 cm.
Length of tubulature	15.0 cm.
Diameter of tubulature	0.9 cm.
Angle of tubulature	75 deg.

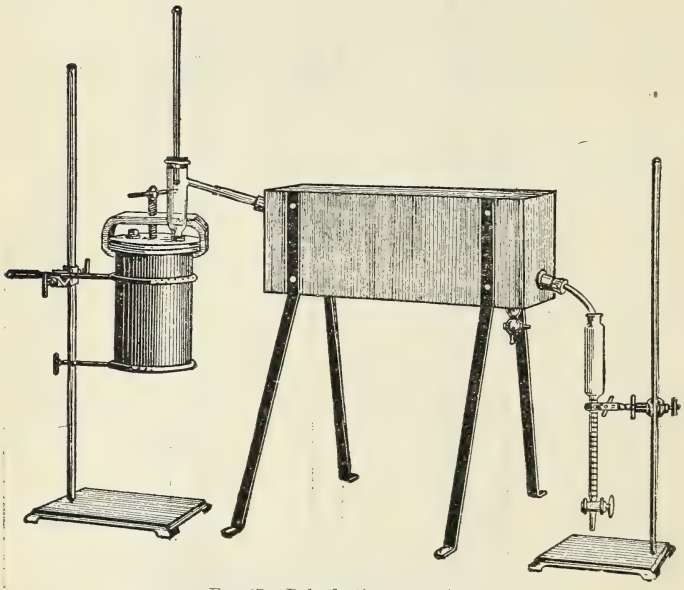

FIG. 27.—Dehydrating apparatus.

A variation of 3 per cent from the above measurements will be allowed.

(*b*) *Thermometer.*—The thermometer shall conform to the following requirements:

It shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A. S. T. M. Distillation."

The thermometer shall be graduated from 0° to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

	Mm.
Total length, maximum	385
Diameter of stem (permissible variation 0.5 mm.)	7
Diameter of bulb, minimum (shall not exceed diameter of stem)	5
Length of bulb (permissible variation 2.5 mm.)	12.5
Distance from 0° to bottom of bulb (permissible variation 2.5 mm.)	30
Distance from 0° to 400° (permissible variation 10 mm.)	295

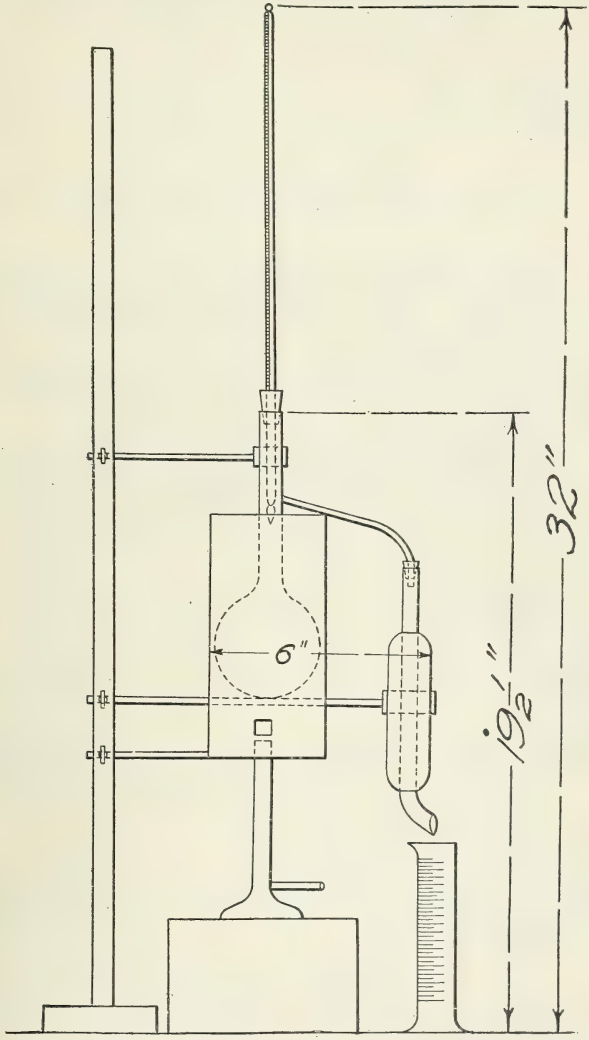

FIG. 28.—Distillation apparatus with vertical condenser.

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error shall not exceed the following:

	°C.
From 0° to 200° C	0.5
From 200° to 300° C	1.0
From 300° to 375° C	1.5

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure, at the time of test, and plunged into free flow of steam, the meniscus shall pass the point 10° C. below the boiling point of water in not more than 6 seconds.

The thermometer shall be set up as for the distillation test, using water, naphthalene and benzophenone as distilling liquids. The correctness of the thermometer shall be checked at 0° and 100° C. after each third distillation until seasoned.

(*c*) *Condenser.*—The condenser tube shall have the following dimensions:

	Mm.
Adapter	70
Length of straight tube	185
Width of tube	12 to 15
Width of adapter end of tube	20 to 25

(*d*) *Stands.*—Two iron stands shall be provided, one with a universal clamp for holding the condenser, and one with a light grip arm with a cork-lined clamp for holding the flask.

(*e*) *Burner and shield.*—A Bunsen burner shall be provided, with a tin shield 20 cm. long by 9 cm. in diameter. The shield shall have a small hole for observing the flame.

(*f*) *Cylinders.*—The cylinders used in collecting the distillate shall have a capacity of 25 c. c., and shall be graduated in 0.1 c. c.

(4) The apparatus shall be set up as shown in figure 28, the thermometer being placed so that the top of the bulb is opposite the middle of the tubulature. All connections should be tight.

(5) One hundred cubic centimeters of the dehydrated material to be tested shall be placed in a tared flask and weighed. After adjusting the thermometer, shield, condenser, etc., the distillation is commenced, the rate being so regulated that 1 c. c. passes over every minute. The receiver is changed as the mercury column just passes the fractionating point.

The following fractions should be reported:

Start of distillation to 110° C.
110 to 170° C.
170 to 235° C.
235 to 270° C.
270 to 300° C.
Residue.

To determine the amount of residue, the flask is weighed again when distillation is complete. During the distillation the condenser tube shall be warmed when necessary to prevent the deposition of any sublimate. The percentages of fractions should be reported both by weight and by volume.

32. STANDARD METHOD FOR DETERMINATION OF SOFTENING POINT OF BITUMINOUS MATERIALS OTHER THAN TAR PRODUCTS (RING-AND-BALL METHOD).

(A. S. T. M. Standard Method, Serial Designation, D 36–19.)

NOTE.—It was recommended by the conference that this method be followed for both asphaltic and tar products.

(1) The softening of bituminous materials generally takes place at no definite moment or temperature. As the temperature rises, they gradually and imperceptibly change from a brittle or exceedingly thick and slow flowing material to a softer and less viscous liquid. For this reason, the determination of the softening point must

be made by a fixed, arbitrary, and closely defined method if the results obtained are to be comparable.

I. APPARATUS.

(2) The apparatus shall consist of the following:

(*a*) A brass ring 15.875 mm. ($\frac{5}{8}$ inch) in inside diameter and 6.35 mm. ($\frac{1}{4}$ inch) deep; thickness of wall, 2.38 mm. ($\frac{3}{32}$ inch) permissible variation on inside diameter and thickness of ring, 0.25 mm. (0.01 inch). This ring shall be attached in a convenient manner to a No. 15 B. & S. gauge brass wire (diameter 1.79 mm.=0.0703 inch). (See fig. 29.)

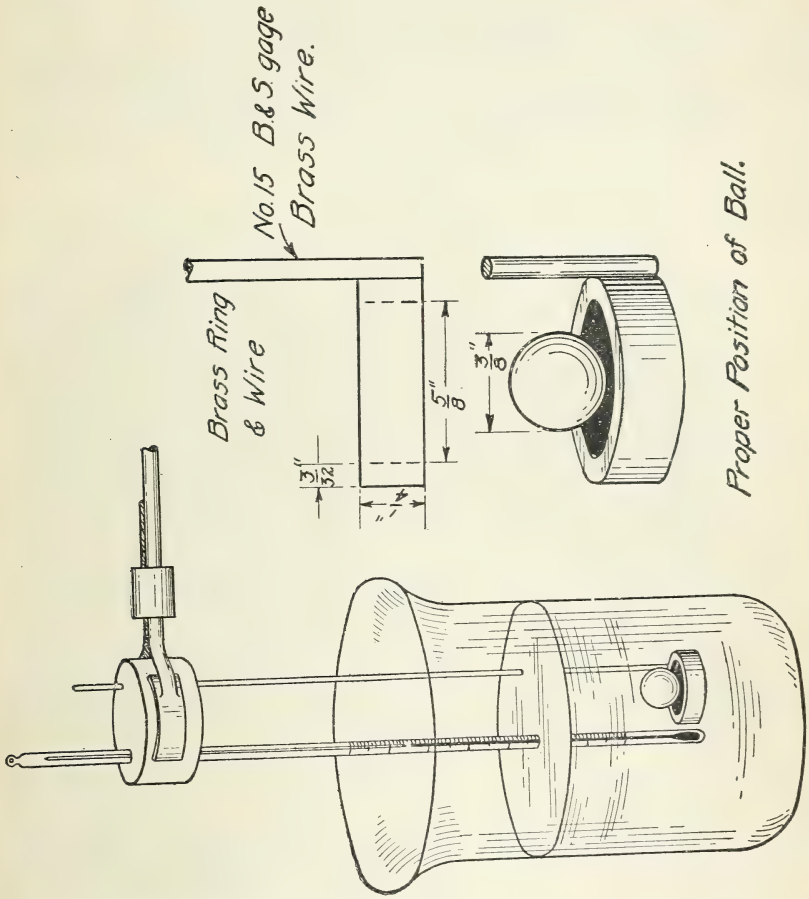

FIG. 29.—Details and assembly of apparatus for determining softening point, ring-and-ball method.

(*b*) A steel ball 9.53 mm. ($\frac{3}{8}$ inch) in diameter weighing between 3.45 and 3.55 grams.

(*c*) A glass vessel, capable of being heated, not less than 8.5 cm. (3.34 inch) in diameter by 10.5 cm. (4.13 inch) deep. (A 600 c. c. beaker, Griffin low form, meets this requirement.)

(*d*) A thermometer which shall conform to the following specifications:

Total length	370 to 400 mm. (14.57 to 15.75 inches).
Diameter	6.5 to 7.5 mm. (0.256 to 0.295 inch).
Bulb length	not over 14 mm. (not over 0.55 inch).
Bulb diameter	4.5 to 5.5 mm. (0.177 to 0.215 inch).

The scale shall be engraved upon the stem of the thermometer, shall be clear cut and distinct, and shall run from 0° to 80° C. (32° to 176° F.) in $\frac{1}{5}$° centigrade divisions. It shall commence not less than 7.5 cm. (2.95 inches) above the bottom of the bulb. The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and be so annealed as not to change its readings under conditions of use. It shall be correct to 0.25° C. (0.45° F.) as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the United States Bureau of Standards.

II. PREPARATION OF SAMPLE.

(3) The sample shall be melted and stirred thoroughly, avoiding incorporating air bubbles in the mass, and then poured into the ring so as to leave an excess on cooling. The ring, while being filled, should rest on a brass plate which has been amalgamated to prevent the bituminous material from adhering to it. After cooling the excess material shall be cut off cleanly with a slightly heated knife.

III. TESTING.

(A) Bituminous Materials Having Softening Points 80° C. (176° F.) or Below.

(4) Assemble the apparatus as shown in figure 29. Fill the glass vessel to a depth of substantially 8.25 cm. (3.25 inches) with freshly boiled, distilled water at 5° C. (41° F.). Place the ball in the center of the upper surface of the bitumen in the ring and suspend it in the water so that the lower surface of the filled ring is exactly 2.54 cm. (1 inch) above the bottom of the glass vessel and its upper surface is 5.08 cm. (2 inches) below the surface of the water. Allow it to remain in the water for 15 minutes before applying heat. Suspend the thermometer so that the bottom of the bulb is level with the bottom of the ring and within 0.635 cm. ($\frac{1}{4}$ inch), but not touching, the ring.

(5) Apply the heat in such a manner that the temperature of the water is raised 5° C. (9° F.) each minute.

(6) The temperature recorded by the thermometer at the instant the bituminous material touches the bottom of the glass vessel shall be reported as the softening point.

(7) The rate of rise of temperature shall be uniform and shall not be averaged over the period of the test. The maximum permissible variation for any minute period after the first three shall be 0.5° C. (0.9° F.). All tests in which the rate of rise in temperature exceeds these limits shall be rejected.

(B) Bituminous Materials Having Softening Points Above 80° C. (176° F.).

(8) Use the same method as given under (A) except that glycerine shall be used instead of water and that the thermometer shall conform to the following specifications:

Total length	370 to 400 mm. (14.57 to 15.75 in.)
Diameter of stem	6.5 to 7.5 mm. (0.256 to 0.295 in.)
Bulb length, not over	14 mm. (not over 0.55 in.)
Bulb diameter	4.5 to 5.5 mm. (0.177 to 0.217 in.)

The graduations shall be from 30° to 160° C. in $\frac{1}{2}$° C. and shall be clear cut and distinct. The 30° mark shall be at least 75 mm. above the bottom of the bulb. The length between the 30° mark and the 160° mark shall be between 230 mm. and 275 mm.

The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and so annealed as not to change its readings under conditions of use. It shall be correct to 0.25° C. as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the Bureau of Standards.

IV. ACCURACY.

(9) The limit of accuracy of the test is 0.5° C. (0.9° F.).

V. PRECAUTIONS.

(10) The use of freshly boiled distilled water is essential, as otherwise air bubbles may form on the specimen and affect the accuracy of the results. Rigid adherence to the prescribed rate of heating is absolutely essential in order to secure accuracy of results.

A sheet of paper placed on the bottom of the glass vessel and conveniently weighted will prevent the bituminous material from sticking to the glass vessel, thereby saving considerable time and trouble in cleaning.

33. METHOD FOR EXAMINATION OF BITUMINOUS MIXTURES.

A. CENTRIFUGAL METHOD.

The extractor shown in figure 30 was designed upon lines suggested by an examination of machines in use by A. E. Schutte and C. N. Forrest.[10] It consists of a one-fifth horsepower, 1,100 revolutions per minute vertical-shaft electric motor, *a*, with the shaft projecting into the cylindrical copper box *b*, the bottom of which is so inclined as to drain the spout *c*. A three-sixteenths-inch circular brass plate 9½ inches in diameter is shown in *d*, and upon this rests the sheet-iron bowl *e*, which is 8½ inches in diameter by 2⅝ inches high, and has a 2-inch circular hole in the top. Fastened to the inner side of the bowl is the brass cup *f*, having a circle of one-eighth-inch holes for the admission of the solvent, and terminating in the hollow axle, which fits snugly through a hole at the center of the brass plate. The bowl may be drawn firmly against a felt-paper ring *g*, three-fourths inch wide, by means of the 2½-inch milled nut *h*, for which the hollow axle is threaded for a distance of three-fourths inch directly below the upper surface of the plate. The axle fits snugly over the shaft of the motor, to which it is locked by a slot and cross pin, *i*.

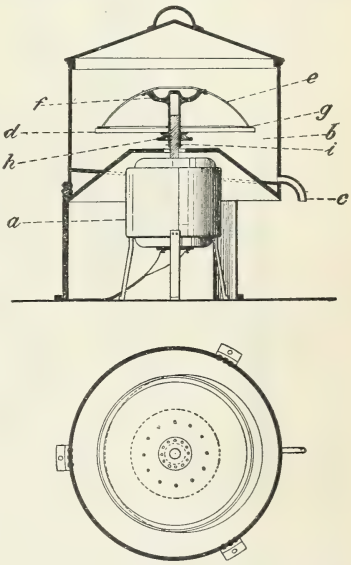

FIG. 30.—Centrifuge extractor. (Reeve type.)

The aggregate is prepared for analysis by heating it in an enamel-ware pan on the hot plate until it is sufficiently soft to be thoroughly disintegrated by means of a large spoon. Care must be taken, however, that the individual particles are not crushed. If a section of pavement is under examination, a piece weighing somewhat over 1 kilogram may be cut off with hammer and chisel. The disintegrated aggregate is then allowed to cool, after which a sufficient amount is taken to yield on extraction from 50 to 60 grams of bitumen. It is placed in the iron bowl and a ring three-fourths of an inch wide, cut from the felt paper, is fitted on the rim, after which the brass plate is placed in position and drawn down tightly by means of the milled nut. If the bitumen is to be recovered and examined, the felt ring should be previously treated in the empty extractor with a couple of charges of carbon disulphide in order to remove any small

[10] Any extractor of similar design may be used.

amount of grease or resin that may be present, although a proper grade of felt should be practically free from such products. The bowl is now placed on the motor shaft and the slot and pin are carefully locked. An empty bottle is placed under the spout and 150 c.c. of carbon disuphide (carbon tetrachloride, benzole, or chloroform may also be used as solvents) is poured into the bowl through the small holes. The cover is put on the copper box and, after allowing the material to digest for a few minutes, the motor is started slowly at first in order to permit the aggregate to distribute uniformly. The speed should then be increased sufficiently by means of the regulator to cause the dissolved bitumen to flow from the spout in a thin stream. When the first charge has drained, the motor is stopped and a fresh portion of disulphide is added. This operation is repeated from four to six times with 150 c.c. of disulphide. With a little experience the operator can soon gauge exactly what treatment is necessary for any given material. When the last addition of solvent has drained off, the bowl is removed and placed with the brass plate uppermost on a sheet of manila paper. The brass plate and felt ring are carefully laid aside on the paper and, when the aggregate is thoroughly dry, it can be brushed on a pan of the rough balance and weighed. The difference between this weight and the original weight taken shows the amount of bitumen extracted. The aggregate may then be tested as occasion requires.

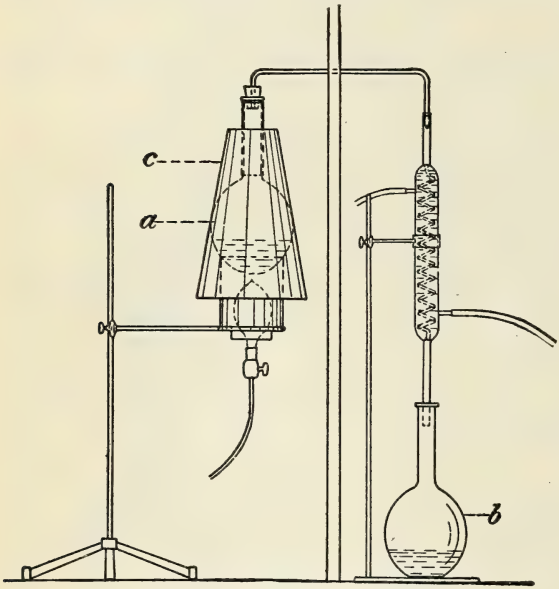

FIG. 31.—Recovery apparatus.

When it is desired to recover and examine the bitumen, the apparatus shown in figure 31 will be found convenient and fairly safe for the distillation and recovery of such inflammable solvents as carbon disulphide. In the laboratory of the Bureau of Public Roads this apparatus is arranged so that the glass tubing passes through a stone partition between two sections of a small hood, thus keeping the distilling and receiving apparatus entirely separated.

The solution of bitumen should be allowed to stand overnight in order to permit the settling of any fine mineral matter that is sometimes carried through the felt ring in the extractor. The solution is then decanted into the flask *a*, and the solvent is driven off by means of heat from an incandescent lamp until the residue is of a thick sirupy consistency. Meanwhile the solvent is condensed and recovered in the flask *b*. The residue is poured into an 11-cm. porcelain evaporating dish and evaporated on a steam bath. The most scrupulous care must be taken at all times that no flames are in its immediate vicinity. Evaporation is carried on at a gentle heat, with continual stirring, until foaming practically ceases. It is advisable to have a large watch glass at hand to smother the flames quickly should the material ignite. As the foaming subsides, the heat of the steam bath may be gradually raised, and evaporation is continued until the bubbles beaten or stirred to the surface of the bitumen fail to give a blue flame or odor of sulphur dioxide when ignited by a small gas jet.

The dish of bitumen should then be set in a hot-air oven maintained at 105° C. for about an hour, after which it is allowed to cool. Its general character is noted and any tests for bitumens that are necessary are then made upon it.

The difference between the final aggregate and the original amount taken gives the amount of bitumen extracted, which is subject to correction, dependent on the amount of ash determined from the washings.

Ash correction shall be made in the following manner: The total solution of bitumen, well stirred, is rapidly measured and an aliquot portion taken, usually 100 c. c., and poured into a previously weighed suitable flat-bottom dish, preferably quartz. The solvent is evaporated over a very low flame and the residual coke is then ignited with a burner capable of furnishing high temperature, such as a Meker. (Caution: When an inflammable solvent is used evaporation should be conducted on a steam bath and care should be taken that no flames are in the immediate vicinity.) The dish and contents are then cooled in a desiccator and the percentage of ash calculated.

B. HOT EXTRACTION METHOD.

The New York Testing Laboratory extractor consists of a large brass cylinder, through the bottom of which projects a 16-candlepower incandescent carbon-filament bulb to supply heat to the extraction apparatus proper, which is held in the upper portion of the cylinder. This apparatus is composed of a cylindrical brass vessel for holding the solvent, a cylindrical wire basket made of 80-mesh wire cloth, suspended in the cylinder, and an inverted conical condenser which serves as a top.

The aggregate is prepared for analysis by heating it in a tin dish on the hot plate until it is sufficiently soft to be disintegrated by means of a large spoon. The disintegrated aggregate is then allowed to cool. Five hundred grams of aggregates containing particles larger than one-half inch in diameter and 300 grams of aggregates with all particles smaller than one-half inch are then closely packed in the wire basket and covered with a disk or wad of absorbent cotton or felt. From 175 to 200 c. c. of carbon disulphide are next placed in the inside vessel, in which the wire basket should be suspended. The top is then placed in position and cooling water circulated through it. Heat is applied by means of the electric-light bulb. The solvent is boiled in the lower part of the extractor and condenses on the under surface of the top, from which it drips upon the wad of absorbent cotton and then percolates through the sample. A complete extraction may be made in three hours. At the end of this time the apparatus is allowed to cool and the basket containing the extracted aggregate carefully removed. After thoroughly drying, the aggregate is placed upon a pan of the rough balance and weighed. The difference between this weight and the original weight taken shows the amount of bitumen extracted which is calculated upon a percentage basis of the original. This figure should be corrected for fine mineral matter which passes through the meshes of the wire basket as follows: The solution of extracted bitumen is thoroughly agitated and measured in a glass graduate. Five or ten cubic centimeters are then poured into a weighed platinum crucible or dish, burned, and ignited to ash. The amount of mineral matter in the entire solution may then be calculated from the amount of ash produced from that portion ignited. The total percentage of such ash is then deducted from the percentage of bitumen already calculated in order to obtain the true percentage of bitumen. The amount of this correction will ordinarily vary from 0.1 per cent in uniformly coarse aggregates to 1 or 2 per cent in the analysis of aggregates containing a considerable amount of very fine mineral matter.

SUGGESTED METHOD FOR EXAMINATION OF BITUMINOUS MORTARS.

Bituminous mortars may be extracted by the use of bronze tubes which are capable of being whirled in the type of centrifuge similar to the Babcock milk tests. This method is based on decantation of the supernatant solvent. The difference between

the final aggregate and the original amount taken gives the amount of bitumen extracted which is subject to correction of the amount of ash determined from the washings. Ash correction to be made as given under A.

34. DETERMINATION OF WATER IN BITUMINOUS MATERIALS.

The apparatus consists of a copper still, 6 by 3½ inches; a ring burner to fit the still; connecting tube; condenser trough; condenser tube; separatory funnel; and a thermometer, 0°–250° C.

In the case of coal-tar material, 50 c. c. of coal tar naphtha or light oil shall be measured into a 250 c. c. graduated cylinder, and 200 c. c. of the material to be tested shall be added. In the case of petroleum products, petroleum naphtha may be used. The contents shall be transferred to the copper still and the cylinder shall be washed with 100 to 150 c. c. more of naphtha, and the washings added to the contents of the still. The lid and clamp shall be attached, using a paper gasket, and the apparatus set up as shown in figure 27. The condenser trough should be filled with water. Heat should be applied by means of the ring burner and distillation, continued, until the vapor temperature has reached 205° C. (401° F.). The distillate shall be collected in the separatory funnel, in which 15 to 20 c. c. of benzol or naphtha have been pre-

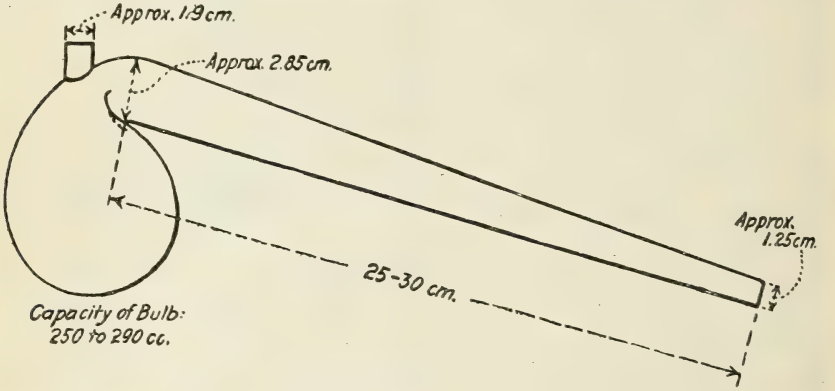

FIG. 32.—Retort for distillation test.

viously placed. This effects a clean separation of the water and oil. The reading shall be made after twirling the funnel and allowing to settle for a few minutes. The percentage shall be figured by volume.

When fresh supplies of naphtha or light oil are obtained they shall be tested to determine freedom from water.

It is recommended that further investigation be made on this method by using a water-saturated solution of naphtha. This criticism has been made on the method due to the fact that naphtha possibly possesses an affinity for water.

35. TESTS OF PREMOLDED JOINT FILLERS.

The bituminous material before manufacture into the premolded joint fillers should be subjected to the tests as for poured expansion joint fillers.

36. TESTS FOR EMULSIONS.

The essential tests on emulsions are per cent of water and quality of bitumen.

The percentage of water may be obtained by the methods of water determinations in test No. 34 without the addition of naphtha or benzol. The emulsion can be broken

down by the addition of a 10 per cent solution of calcium chloride. The separated bituminous material is then kneaded by hand to separate all contained water and then subjected to the usual quality tests.

37. DETERMINATION OF PARAFFIN SCALE.

It is recommended that the paraffin scale determination be omitted on account of difficulty encountered in obtaining dependable results due to the inaccuracy of any methods which have heretofore been introduced.

38. STANDARD METHOD FOR DISTILLATION OF CREOSOTE.

(Extract from A. S. T. M. Standard Method, Serial Designation: D 38-18.)

(1) (*a*) *Retort.*—This shall be a tubulated glass retort of the form and approximate dimensions shown in figure 32, with a capacity of 250 to 200 c. c. The capacity shall

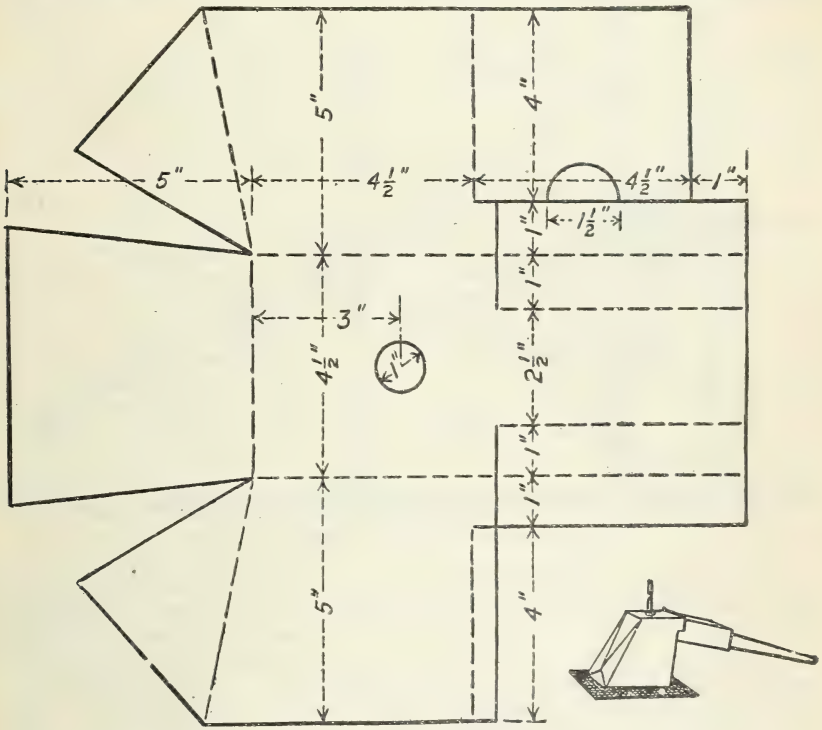

FIG. 33.—Asbestos shield.

be measured by placing the retort with the bottom of the bulb and the end of the offtake in the same horizontal plane, and pouring water into the bulb through the tubulature until it overflows the offtake. The amount remaining in the bulb shall be considered its capacity.

(*b*) *Condenser tube.*—The condenser tube shall be a suitable form of tapered glass tubing of the following dimensions:

	Mm.
Diameter of small end (permissible variation, 1.5 mm.)	12.5
Diameter of large end (permissible variation, 3 mm.)	28.5
Length (permissible variation, 4 mm.)	360.0

(*c*) *Shield.*—An asbestos shield of the form and approximate dimensions shown in figure 33 shall be used to protect the retort from air currents and to prevent radiation. This may be covered with galvanized iron, as such an arrangement is more convenient and more permanent.

(*d*) *Receivers.*—Erlenmeyer flasks of 50 to 100 c. c. capacity are the most convenient form.

(*e*) *Thermometer.*—The thermometer shall conform to the following requirements.

The thermometer shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of

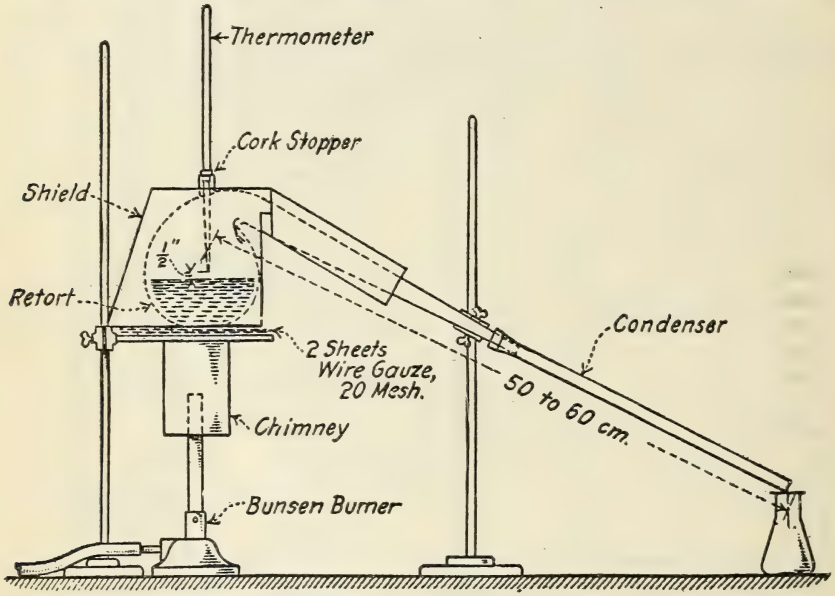

FIG. 34.—Assembled apparatus for distillation test.

the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A. S. T. M. distillation."

The thermometer shall be graduated from 0° to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

	Mm.
Total length, maximum	385
Diameter of stem (permissible variation, 0.5 mm.)	7
Diameter of bulb, minimum (shall not exceed diameter of stem)	5
Length of bulb (permissible variation, 2.5 mm.)	12.5
Distance, 0° to bottom of bulb (permissible variation, 5 mm.)	30
Distance, 0 to 400° (permissible variation, 10 mm.)	295

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error shall not exceed the following:

From 0° to 200° C	0.5° C.
From 200° to 300° C	1.0° C.
From 300° to 375° C	1.5° C.

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure at the time of test and plunged into free flow of steam the meniscus shall pass the point 10° C. below the boiling point of water in not more than six seconds.

(2) The retort shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 6 inches square, as shown in figure 34. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the tubulature with the bottom of the bulb one-half inch from the surface of the oil in the retort.

The exact location of the thermometer bulb shall be determined by placing a vertical rule graduated in divisions not exceeding one-sixteenth inch back of the retort when the latter is in position for the test, and sighting the level of the liquid and the point for the bottom of the thermometer bulb. The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 24 nor less than 20 inches. The burner should be protected from drafts by a suitable shield or chimney (see fig. 34).

(3) Exactly 100 grams of oil shall be weighed into the retort, the apparatus assembled, and heat applied. The distillation shall be conducted at the rate of at least one drop and not more than two drops per second, and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. Fractions shall be collected at the following points: 210°, 235°, 270°, 315°, and 355° C. The receivers shall be changed as the mercury passes the dividing temperature for each fraction. When the temperature reaches 355°, the flame shall be removed from the retort, and any oil which has condensed in the offtake shall be drained in the 355° fraction.

The residue shall remain in the retort with the cork and the thermometer in position until no vapors are visible; it shall then be weighed. If the residue is to be further tested it shall then be poured directly into the brass collar used in the float test or into a tin box and covered and allowed to cool to air temperature. If the residue becomes so cool that it can not be poured readily from the retort, it shall be reheated by holding the bulb of the retort in hot water or steam, and not by the application of flame.

For weighing the receivers and fractions, a balance accurate to at least 0.05 grams shall be used.

During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

When any measurable amount of water is present in the distillate it shall be separated as nearly as possible and reported separately, all results being calculated on a basis of dry oil. When more than 2 per cent of water is present, water-free oil shall be obtained by separately distilling a larger quantity of oil, returning to the oil any oil carried over with the water, and using dried oil for the final distillation.

TENTATIVE TESTS.

39. PROPOSED SOUNDNESS TEST FOR COARSE AGGREGATE.

Immerse 10 small pieces of the rock in a saturated solution of sodium sulphate (Na_2SO_4), for 20 hours, after which place for four hours in a drying oven maintained at 100° C. Repeat the treatment five times. The condition of the rock as to soundness is noted at the end of the test.

Samples which exhibit marked checking, cracking or disintegration shall be considered to have failed in this test.

40. TENTATIVE TEST FOR ABSORPTION OF CONCRETE.

It is recommended that the method of making the absorption test prescribed for cement drain tile in the Standard Specification for Drain Tile, American Society for Testing Materials, Serial Designation C 4–16, be employed for making the absorption test of concrete until a different method is developed.

41. PROPOSED TEST FOR PERCENTAGE OF SHALE IN GRAVEL.

It is suggested that for the separation of shale and other pieces having low specific gravity from concrete aggregates, a solution of zinc chloride ($ZnCl_2$) or some other satisfactory liquid having a specific gravity of approximately 1.95 be used. A sample of the pebbles should be first dried to constant weight at not over 110° C., then placed in a container partially filled with the solution. Agitate for five minutes, skim off the lighter materials and then pour the solution through a sieve which will retain the pebbles. Repeat the operation until the entire sample has been separated. Dry to constant weight, measure the volume of retained material and compute the percentage by volume of shale or other soft material.

42. PROPOSED MODIFICATION OF THE ABRASION TEST FOR BROKEN STONE AND SLAG.

It is recommended that in order to secure data for a revision of the standard abrasion test for stone, abrasion tests on broken stone and slag be run parallel with the regular test (described on page 3) but with a charge of stone made up in the manner prescribed for the charge of gravel for the abrasion test. The purpose is to determine whether it is possible to secure consistent results with a charge for the abrasion test made up from the product of the crusher as it is delivered to the job.

43. PROPOSED ABRASION TEST FOR FINE AGGREGATE.

The following is a tentative method for determining the resistance of the fine aggregate to abrasion. The fine aggregate is washed and dried at a temperature not exceeding 110° C. All material retained on the $\frac{1}{4}$-inch sieve, and all material passing a standard 50-mesh sieve is discarded. Five hundred grams of the portion passing a $\frac{1}{4}$-inch screen and retained on a 50-mesh sieve are placed in a Deval abrasion cylinder with a charge of 250 grams of $\frac{9}{16}$-inch commercial steel bearing balls which shall weigh within 1 per cent of the required 250 grams. The charge in the Deval abrasion cylinder is rotated for 2,000 revolutions at the rate of 33 revolutions per minute. The sample of sand is removed and sieved over a 100-mesh sieve. The sample is prefer-

ably divided into three portions for sieving, the sieving being completed over a sheet of white paper, and is continued until practically no dust passes the sieve when shaking for one minute. The portion retained on the 100-mesh sieve is weighed. Five hundred grams minus the weight of the samples retained on the 100-mesh after abrasion is taken as the loss from abrasion. This weight divided by 5 gives the percentage of wear.

44. PROPOSED FIELD METHODS OF MAKING SIEVE ANALYSIS.

Either volumetric or gravimetric methods may be used on a sample of not less than 500 grams in the volumetric or 200 grams in the gravimetric test. The following methods for making these tests are suggested:

A. VOLUMETRIC METHOD.

Briefly described, the apparatus for this test consists of an outside cylindrical container with telescopic cover, two nests of semicylindrical screens and sieves fitting into the outside cylinder and containing a smaller cylinder with telescopic cover. This small cylinder contains in turn a 10-inch rule having $\frac{1}{10}$-inch divisions and a 200 c. c. graduated cylinder. The entire outfit is very compact, measuring about 14 inches in length and 5 inches in diameter.

Both the outer and inner cylinders are exactly 10 inches in inside depth, the telescopic covers being made to fit the contents of each cylinder. As used at present, there are in each outfit five screens having circular openings $1\frac{1}{2}$-inch, 1-inch, $\frac{3}{4}$-inch, $\frac{1}{2}$-inch, and $\frac{1}{4}$-inch in diameter, respectively, and three sieves of standard 10-mesh, 20-mesh, and 50-mesh, respectively; also three rings of 3-inch, $2\frac{1}{2}$-inch, and 2-inch diameter, respectively, fitting in the cover of the container.

The large cylinder is used when making a screen analysis of a coarse aggregate, while the small cylinder is used in determining the gradation of sand or other fine aggregate. The cylinder is filled with the material to be examined, which is then screened through the screen, or sieve, selected. The portion passing the screen, or sieve, is returned to the cylinder and the height of the material determined, each 0.1 inch corresponding to 1 per cent of the original volume. The portion retained on the screen, or sieve, is determined in the same manner. The percentage passing plus the percentage retained when obtained in this manner add up to more than 100 per cent of the original volume, and if the true percentage passing each screen or sieve is to be reported, the correct value is obtained by dividing the percentage passing each screen or sieve as found above by the total of the measurements obtained for material retained and material passing the screen or sieve. For example, if a gravel shows by measurement 60 per cent retained on a 1-inch screen and 50 per cent passing a 1-inch screen, the true percentage passing the 1-inch screen is—

$$\frac{50}{60+50}=\frac{50}{110}=45\tfrac{1}{2} \text{ per cent.}$$

B. GRAVIMETRIC METHOD.

The apparatus required consists of a spring balance, 200-grams capacity, graduated to tenth-gram divisions and provided with a weighing pan; a series of field sieves well graded in size from a $\frac{1}{4}$-inch screen to a standard 200-mesh sieve. The sample, selected in accordance with the method described, shall be dried in the air or by heating to not over 110° C. The sample for sieve analysis shall be selected from the dried sample by the method of quartering and shall weigh approximately 200 grams. This sample shall be passed successively through the various screens required and the total percentage passing each sieve shall be reported.

45. PROPOSED FIELD DETERMINATION OF CLAY AND SILT.

The apparatus used in this test is the same as that described under the volumetric method of making sieve analysis, test 44. Two hundred c. c. of the sand or other fine aggregate are measured in the graduated cylinder and transferred to the small cylindrical container. Water is added and the sand washed by agitation. The large mineral particles are allowed to settle and the water containing the clay and silt is poured into the large outside cylindrical container. The operation of washing with new portions of fresh water is repeated until the wash water remains clear. The water in the large container is allowed to stand over night to permit the clay and silt to settle out. The clear supernatant water is then poured off and the sediment of clay and silt remaining is transferred to the 200 c. c. graduated cylinder. Water is added to bring the contents of the graduated cylinder to 200 c. c. The volume of sediment in the cylinder is determined at the end of three hours. This volume divided by 2 gives the percentage by volume of clay and silt on a wet basis, three hours standing. This value is usually from 2½ to 4 times the value obtained when determining the clay and silt by dry weight. If we assume, therefore, that the specifications require not more than 5 per cent of clay and silt by dry weight, less than 7½ per cent by volume of clay and silt would indicate that the fine aggregate complies with the specifications, while more than 12 per cent by volume of clay and silt would indicate an excess of material removed in washing.

46. PROPOSED METHODS OF FABRICATING AND TESTING COMPRESSION FIELD SPECIMENS OF CONCRETE.

As a guide to the selection of the sample of the concrete and to the method of making compression specimens in the field see the procedure outlined in Appendix 1, in the report of Committee C–9 in the Proceedings of the A. S. T. M. vol. 17, part 1.

The essential part of the report is as follows:

Sampling the concrete.—Concrete for the test specimens should be taken immediately after it has been placed in the forms. All the material for each sample should be taken from one place. A sufficient number of samples—each large enough to make one test specimen—should be taken at different points so that the specimens made from them will give a fair average of the work. The location from which each sample is taken should be clearly noted for future reference.

In securing samples, the concrete is taken from the mass by a shovel or a similar implement and placed in a large pail or in some other receptacle for transporting to the place where the specimens are molded. Care should be taken to see that each specimen represents the total mixture of the concrete at that place.

Molding the specimen.—The pails containing the samples of concrete should be taken to the place selected for making the test pieces as quickly as possible. To offset segregation of materials during transportation, each sample should then be dumped out of the pail into a nonabsorbent water-tight receptacle and without further mixing immediately placed in the mold. Different samples should not be mixed together, but each sample should make one specimen.

> (The conference recommends that a ½-inch rod 2 feet long should be used for puddling the concrete instead of the ¾-inch rod recommended by Committee C–9. The conference also recommends that the material be placed in the mold in layers 3 inches deep and each layer puddled 20 times with the rod.)

"Ramming should be avoided, but care should be taken to remove air pockets. The freshly made specimen should be struck off and troweled level with the top of the form. The specimen should preferably be capped in the field while it is in the mold so as to be ready for the testing machine. After the concrete has stiffened appreciably and before the molds are removed, neat cement or a rather stiff 1:2 mortar may be used to fill the molds level full. A piece of plate glass or machined metal plate should then be worked around on the top of the mortar until it rests on the form.

This plate should be oiled or a piece of wax paper be placed between it and the concrete. If the forms are carefully made, this will give top and bottom surfaces perpendicular to the sides of the specimens. To prevent the specimen from drying out, it should be covered or otherwise protected. If desired, the mold itself may be buried in sand while the specimen is being molded.

"At the end of 48 hours the specimens should be removed from the mold and buried in damp sand."

(It is the sentiment of the conference that oftentimes in concrete road construction it would be advisable to cure the test pieces along the side of the slab, under conditions similar to those of the pavement.)

"*Testing.*—Ten days prior to the date of test, specimens should be well packed in damp sand or wet shavings and shipped to the testing laboratory, where they should be stored either in a moist room or in damp sand until the date of the test. It is assumed that ordinarily a 28-day test will be made, although tests at 7 and 14 days will give some indications of the results to be expected at 28 days. In case 7-day tests are made, the test pieces should remain at the job as long as possible to harden, and should be shipped so as to arrive at the laboratory in time to make the test on the required date."

47. PROPOSED METHODS OF MAKING TEST SPECIMENS OF CONCRETE IN THE LABORATORY.

The conference recommends that concrete specimens shall be proportioned by volume. The measurements of the unit volumes of aggregate shall be made in accordance with the method outlined under "Weight per cubic foot of aggregate" (p. 11). Volumes required for the given quantity of concrete shall be measured by weighing the requisite amounts of each material. The weight of 1 cubic foot of cement shall be assumed to be 94 pounds. In weighing quantities of a coarse aggregate which varies considerably in size of particles, it is suggested that the aggregate be graded into different sizes and the proper proportions of each of these sizes be used.

In making specimens sufficient quantities of materials [11] to fill a single specimen mold with an excess of 10 per cent should be calculated. The dried materials should be placed on a metallic or other nonabsorbent mixing tray and thoroughly mixed to a uniform color with a square-nose trowel. The requisite amount of water for tempering the mix to proper consistency should be weighed. The dry material should be formed into a crater and about three-fourths of the estimated amount of water added. The entire batch should then be turned until of uniform composition, water being added until the required consistency has been obtained. The amount of water actually used in the mixture should be recorded.

In molding the test pieces, the form should be filled to about one-quarter of its height and thoroughly puddled with a ½-inch rod, using 20 strokes per layer.

From two to four hours after molding, compression specimens should be capped with a layer of neat cement in order that the top of the specimen may present a smooth surface for loading. The cap can be readily formed by means of a glass plate which may be worked down on the neat cement until it rests on top of the form. In order to eliminate shrinkage, the cement for capping should be mixed to a stiff paste before the concrete specimens are made. Adhesion of the concrete to the base of the mold and to the glass can be eliminated by oiling the base and by inserting a sheet of paraffined tissue paper beneath the glass. Specimens should be removed from the forms on the day after they are fabricated, marked, and stored in damp sand, or in a moist chamber until tested.

It is recommended that tests be made at 7, 28, or 90 days; the 28-day period is the most commonly used.

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[11] In most cases it is preferable to use air-dry aggregate.

Compression tests.—The specimen to be used in compression tests shall be a cylinder not less than 6 inches in diameter and 12 inches high. When the diameter of the largest particle of aggregate runs over 2 inches an 8 by 16 inch cylinder is recommended.

The mold should be of metal. A suitable type of mold consists of a 12-inch length of cold-drawn steel tubing 6 inches inside diameter, split along one element, and closed by means of a circumferential band and bolt. Suitable forms can also be made from galvanized iron. Forms should be tight and should rest on level nonabsorbent bases.

At least three specimens should be made to cover any single point in a series of tests. Only one cylinder of a kind should be fabricated at one time.

In testing compression specimens the speed of the moving head of the machine shall travel approximately 0.05 inch per minute when the machine is running idle. The bearing plates of the testing machine shall be brought into direct contact with the end of the specimen, and a spherical bearing block shall be used on top of the test piece. The diameter of the bearing block shall be approximately the same as that of the specimen; the radius of the ball in the block should be not over one-half the radius of the test piece. As the testing head of the machine is brought down upon the top of the cylinder, the lower section of the adjustable block should be oscillated to and fro to insure a central bearing and to avoid pulling the cylinder to one side.

The results of the tests of individual specimens should be reported.

48. PROPOSED TRANSVERSE TESTS OF CONCRETE.

Field specimens.—A slab 30 inches long, 8 or 12 inches wide, and of a depth equal to the depth of pavement should be employed. This specimen should be molded at the edge of the pavement with its long dimension parallel to the length of the road. The forms for separating the test piece from the remainder of the road should be made of sheet metal and should be submerged about three-fourths of an inch below the finished surface of the pavement. In order to provide bearing surfaces and a uniform thickness at the center, three strips of wood 3 inches wide should be placed on the subgrade with their axes running transversely with respect to the axis of the test specimen and wide faces parallel to and equidistant from the top of the pavement. The boards should be placed near each end and at the center of the length of the test piece. Specimens should be tested over a 24-inch span and loaded at the center.

Laboratory specimens.—A specimen 12 inches wide, 8 inches deep, and 30 inches long, to be tested by center load over a 24-inch span, is suggested for laboratory fabrication. The methods of proportioning, mixing, molding, and curing of the transverse test piece should be similar to the method previously outlined.

The modulus of rupture S_r may be found from the following expression: Thus $S_r=\frac{36P}{bd^2}$ in which P is the center load in pounds and b and d the breadth and depth in inches of the slab, respectively.

49. PROPOSED TEST FOR CONSISTENCY OF CONCRETE.

For the determination of the consistency either in the field or in the laboratory the committee proposes the use of the 4 by 8 by 12 inch conical frustum, as shown in figure 35.

In making the test, the thoroughly cleaned frustum should be placed on a level nonabsorbent surface and filled with 3-inch layers of concrete. During filling, the mold should be held down by the operator placing his toes on the lip at the bottom of the mo d. As each layer of material is introduced it should be puddled by a stirring motion with a one-half-inch rod to uniformly distribute the material.

After the upper layer has been placed the top shall be struck off and the mold removed by slowly pulling it vertically upward. The height of the frustum shall be measured and the slump calculated from the difference of the height of the mold and the frustum.

In making the slump test in the laboratory or in the field it is recommended that the form be filled immediately after mixing and withdrawn three minutes after mixing has been completed.

When central mixing plants are used slump tests shall be made at the plant and at the end of the haul. At the plant the sample of concrete shall be taken after the

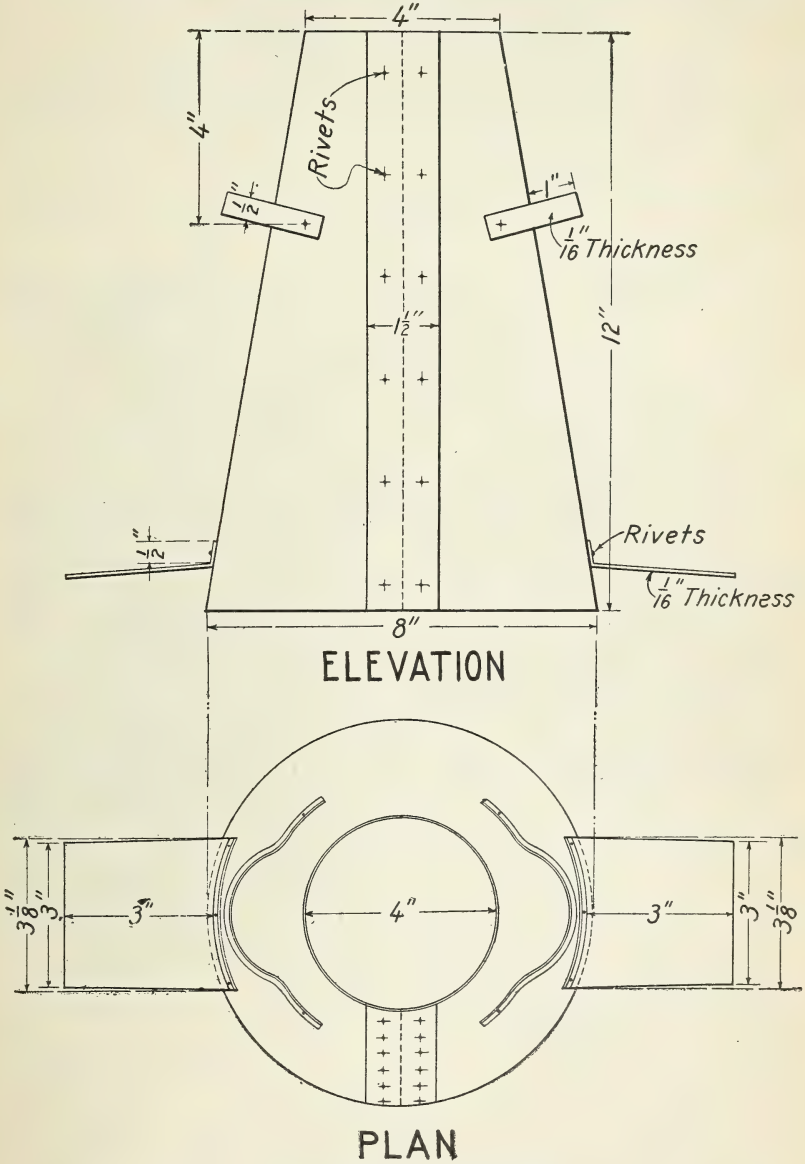

FIG. 35.—Cone for concrete slump test.

entire batch has been discharged from the mixer. At the end of the haul the slump sample shall be taken from the batch after it has been dumped on the subgrade. The slump at the points of deposition shall be suitable for the particular type of finish employed.

50. DETERMINATION OF PERCENTAGE OF PIGMENT IN PAINTS.

The per cent of pigment shall be determined by extracting a weighed amount of from 10 to 50 grams of the paint, or from 5 to 30 grams of the paste, several times with light paraffin naphtha (preferably 86° B.), using approximately 50 c. c. of fresh naphtha for each extraction, and repeating the operation until the liquid of extraction remains clear and colorless. The amount taken for analysis may be varied according to the nature of the material. The extraction and washing of the pigment shall be completed by the use of two or three portions of about 50 c. c. of ether, the pigment finally dried to constant weight at 105° C., and the per cent of pigment by weight calculated. One hundred less the per cent of pigment found shall be considered as the per cent of vehicle.

51. TESTS FOR THE AMOUNT OF SPELTER COATING ON CULVERT METAL.

The amount of spelter coating shall be determined by one of the following methods:

(*a*) *Lead acetate method.*—The solution used for making this test is prepared by dissolving 400 grams of crystallized lead acetate in 1 liter of water. When dissolved, add 4 grams of finely powdered litharge and agitate until most of it has dissolved. The solution is allowed to settle and the clear portion decanted for use.

Ordinary glass tumblers have been found very satisfactory to use in making this test, as they are the right diameter to enable the sample to be maintained in an upright position without supports.

Use several 2¼-inch by 2¼-inch pieces cut accurately to $\frac{1}{64}$ inch and weighed to three decimal places. Weigh and submerge separately, for 3 minutes, in tumblers containing solution of lead acetate. The samples are then taken out and the adherent lead, removed with a stiff brush or steel spatula. A burnishing action should be avoided, as under some conditions closely adherent lead will be plated out on the iron. Repeat the 3-minute immersions in the lead acetate solution until a bright surface is exposed. Four 3-minute immersions are usually sufficient. Wash specimens in water, dry, and weigh. The loss in grams will also be the loss in ounces per square foot.

(*b*) *Antimony hydrochloric acid method.*[12]—Use several 2¼-inch by 2¼-inch pieces, weighed to three decimal places. They are then immersed separately for one-half minute in hydrochloric acid of specific gravity 1.20 to which has been added 5 c. c. of antimony chloride solution prepared by dissolving 20 grams of antimony trioxide in 1,000 c. c. of hydrochloric acid of specific gravity 1.20. The pieces are scrubbed with a brush under running water, dried, and weighed again. About 100 c. c. of the hydrochloric acid will usually be sufficient for immersing the test pieces if a 200 c. c. beaker is used. The same portion of hydrochloric acid may be used for at least 5 test pieces. Five cubic centimeters of the antimony chloride solution, however, should be added for each sample on account of the antimony being removed from the solution by the iron. The test pieces being exactly 2¼ inches by 2¼ inches, the loss in grams will also be the loss in ounces per square foot.

[12] This method is discussed at length in the Proceedings of A. T. M. 1915, p. 120.

RECOMMENDED STANDARD METHODS OF SAMPLING.

52. SAMPLING BROKEN STONE.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the stone is to be accepted or rejected, also from every —— cubic yards quarried, or when the quality or appearance of the stone changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—(*a*) Sampling for quality: Samples shall be taken either from the quarry or from cars as directed by the engineer, and shall be sound interior rock, representative of that which it is proposed to use. Mixed samples may be taken if deemed necessary by the engineer.

(*b*) Sampling for size: Samples of the crusher product shall be taken either at the crusher or from cars as directed by the engineer. The sample shall be mixed from runs of the crusher on different days, or if taken from cars, shall be taken from both ends and top and bottom of the car.

(4) *Amount and size of sample.*—(*a*) Sampling for quality: A sample shall weigh between 25 and 40 pounds and shall consist of pieces of rock at least 1½ inches in size and one piece at least 3 by 4 by 6 inches, free from seams and cracks, and with bedding plane marked.

(*b*) Sampling for size: A sample for size shall weigh not less than 10 pounds for materials of three-quarters inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of quarry investigations, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of rock.

Notification of sampling containing the above data shall be forwarded separately to the laboratory immediately upon taking the sample.

53. SAMPLING BROKEN SLAG.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the slag is to be accepted or rejected, also from every —— cubic yards quarried, or when the quality or appearance of the slag changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—(*a*) Sampling for quality: Samples shall be taken either from the deposit or from cars as directed by the engineer, and shall be representative of that which it is proposed to use. Mixed samples may be taken if deemed necessary by the engineer.

(*b*) Sampling for size: Samples of the crusher product shall be taken either at the crusher or from cars as directed by the engineer. The samples shall be mixed from runs of the crusher on different days, or if taken from cars, shall be taken from both ends and top and bottom of the car.

(4) *Amount and size of sample.*—(*a*) Sampling for quality: A sample shall weigh between 25 and 40 pounds and shall consist of pieces of slag at least 1¼ inches in size and one piece at least 3 by 4 by 6 inches.

(*b*) Sampling for size: A sample for size shall weigh not less than 10 pounds for material of three-quarters inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of quarry investigations, owner, quantity available, whether material from the same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of slag.

Notification of sampling containing the above data shall be forwarded separately to the laboratory immediately upon taking the sample.

The conference, recognizing that in general slag is not a uniform product, recommends that special care should be taken to get a representative sample.

54. SAMPLING STONE BLOCK.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken at least —— days before the block is to be accepted or rejected, or when the quality or appearance of the block changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—Samples shall be taken either from the quarry or from cars, as directed by the engineer. They shall be representative of the block which it is proposed to use; and no samples shall include blocks that would be rejected by a visual examination.

(4) *Amount and size of sample.*—The sample shall consist of at least 10 blocks. The bedding plane shall be marked on at least 2 blocks.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes and shall be accompanied by a card in the container, or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, whether material from same source has been previously used, where and for what purpose and with what results, initial cost of block, haul to nearest point on road, average haul to job, character of haul, and space for remarks.

Notification of sampling, containing the above data shall be forwarded separately to the laboratory immediately upon taking the sample.

55. SAMPLING GRAVEL.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the gravel is to be accepted or rejected, also from every ——

cubic yards excavated, or when the quality or appearance of the gravel changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—(*a*) Sampling at the pit: Enough samples shall be taken to represent an average of the material. An individual sample must be taken through a full vertical section of that material which it is proposed to use at the point selected. Each sample shall be taken from a freshly exposed vertical face.

(*b*) Sampling from cars, barges, etc.: Enough samples shall be taken, as directed by the engineer, to represent average composition. Samples from cars shall be taken from both ends and from top and bottom of the car.

(4) *Amount and size of sample.*—(*a*) Sampling for quality: For screened gravel sample shall weigh 25 to 30 pounds. For bank gravel sample shall weigh 50 to 75 pounds.

(*b*) Sampling for size: A sample for size shall weigh not less than 10 pounds for materials of three-quarter-inch maximum diameter or less. Samples of materials of other sizes shall increase in weight to a maximum of approximately 60 pounds, varying with the size and weight of the largest pieces represented by the sample. The sample shall be representative of the product as delivered for use.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and, in case of pit or bank investigation, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of gravel.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

56. SAMPLING SAND.

(1) *By whom taken.*—Samples are to be taken by the engineer or his authorized representative.

(2) *When taken.*—Samples are to be taken from the proposed source of supply at least —— days before the sand is to be accepted or rejected, also from every —— cubic yards excavated, or when the quality or appearance of the sand changes, and at such other times as may be directed by the engineer.

(3) *Where and how taken.*—Samples shall be taken from freshly exposed portions of the deposit as directed by the engineer. Mixed samples may be taken if deemed necessary.

In general, the number of samples shall be sufficient to cover the extreme variation of quality in that part of the deposit which is proposed to be used.

(4) *Amount and size of sample.*—Each sample, whether individual or composite, shall weigh between 10 and 15 pounds.

(5) *Marking and shipping.*—Samples shall be shipped in tight boxes or bags and shall be accompanied by a card in the container or securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, proposed purpose to which the material is to be put, space for remarks, and in case of source investigation, owner, quantity available, amount and character of stripping, whether material from same source has been previously used, where and for what purpose, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of sand.

Notification of sampling, containing the above data, shall be forwarded separately to the laboratory immediately upon taking the sample.

57. SAMPLING SEMIGRAVEL, TOP SOIL, AND SAND-CLAY.

Samples of materials of this class shall be of two kinds: Class I, samples of the raw material taken from the natural deposit; Class II, samples of the loose material after being mixed in place on the roadbed and before consolidation.

Class I samples shall be used simply as preliminary evidence of the suitability of the aggregate, subject to admixture of one or more ingredients to adjust the composition to the limits set forth in the specifications.

The final acceptance of the material as satisfying the specifications shall be based on Class II samples.

Standard containers.—(1) A three-compartment box of pasteboard, wood, or metal, outside dimensions 5 by 10 by 10 inches; or (2) close woven bags or sacks of material which do not allow sifting out of fine particles, dimensions 6 inches wide by 12 inches long.

Labeling.—Each compartment in the box container must contain a label showing at what depth the contents were taken. The whole sample shall be accompanied by a card, securely attached thereto, stating date, by whom taken, by whom submitted, source of supply, exact location where sample was taken, position within the deposit where taken, owner, quantity available, amount and character of stripping, if any, whether material from same source has been previously used, where, and with what results, haul to nearest point on road, average haul to job, character of haul, initial cost of material.

When bag containers are used, one complete sample shall comprise 3 bags, each bag labeled as to depth from which the material is taken.

Each bag, or, if preferred, a larger receptacle containing the three bags, is to be labeled with the information detailed above.

How to take Class I samples.—For each 1 acre or less of area two samples must be taken, one a local sample and the other a composite sample.

The local sample is to be taken near the center of the area and is intended to represent the vertical average of the material at that point. It shall be taken in three layers, each layer —— inches thick, according to the method described as follows:

The material is to be loosened over a 3 by 3 foot area to the specified depth, usually 4 inches. The loose material is to be intermixed with a shovel and the sample for one compartment of the box container or one of the bags is to be taken therefrom.

The remaining loose material is to be shoveled out and discarded. The second layer is to be loosened to equal depth, usually 4 inches, to be intermixed as before, and a second compartment or bag is to be filled. The same procedure shall apply to the third layer and the filling of the third compartment or bag.

In exceptionally thick deposits the depth of each layer or the number of layers may be increased to cover the entire thickness of the deposit.

The composite sample is to be taken as follows: Roughly divide the area to be represented by the sample into squares not exceeding 50 feet in size. At the corners of all squares loosen a 3 by 3 foot area to a depth of ——[13] inches. Thoroughly mix the loose material. Carry an equal amount of the material from each such point to a central point and intimately mix the various samples. Not less than 200 pounds of material must be so mixed. From the center of the pile of mixed material fill a container and label for shipment.

Where the material occurs as a substratum sink no less than four 3 by 3 foot pits per acre or smaller area to intersect the material. Remove the covering, and sample the exposed bed as for a local sample described above.

How to take Class II samples.—These are the most important samples and should be taken by the engineer or competent inspector while work is in progress.

[13] A depth of 8 inches is suggested.

When the materials have been spread and intimately mixed in accordance with properly drawn clauses covering methods of construction, the engineer should fill a container at intervals of —— [14] feet, along the road, and also at such other points as his judgement may dictate, where evidence of unsatisfactory mixing is apparent.

Very prompt examination of these samples should be made in order that defects of composition may be remedied by the builder before consolidation has progressed.

58. SAMPLING BITUMINOUS MATERIALS.

GENERAL RECOMMENDATIONS.

All samples should be selected to represent as nearly as possible an average of the material, care being taken that they are not contaminated with other materials. It is recommended also that special care be taken to forward the samples in clean, suitable containers, and wherever possible all materials should be sampled at the point of manufacture, and sufficiently in advance of shipment of the material represented to allow for the testing and reporting upon the samples before shipment. When impracticable to take samples at the point of manufacture they should be taken by the engineer or inspector from the shipment immediately upon delivery.

In collecting samples, if there is any doubt of the homogeneity of the material it is recommended that individual samples be lifted as hereinafter described, and such samples should be forwarded to the laboratory, where tests should be conducted to determine the uniformity, after which a composite sample of equal parts of the individual samples may be mixed for complete tests.

Samples should be taken as frequently as neccessary to insure the uniformity of the material.

Marking samples.—Samples should be marked for identification in such manner that the identification will not be removed in transit. Notification of sampling containing this identification, together with such other information as is required or of advantage to the laboratory, should be separately forwarded to the laboratory immediately upon taking the sample.

Size of samples.—No sample should be less than 1 quart, whether for complete testing or for individual test.

Plant sampling.—Drip samples are recommended. In taking drip samples, the pumping should be continued until sufficient time has elapsed to clean the line before sample is taken. The drip valve should be so regulated that the collecting of the material continues through the entire time of pumping.

When impracticable to follow the above method it is recommended that samples be taken from the storage tank at three different levels.

Material in barrels or drums at a plant should be sampled by taking samples from not less than 3 per cent of the containers.

Whenever possible, the portion of the sample from each drum or barrel should be taken from near the heart of the barrel after it has been split open. Where samples must be taken from the top of the barrel, the material lying within 3 inches of the surface should not be included. A hatchet or any sharp-pointed tool is suitable for the purpose of digging into the barrel. (IMPORTANT.—Do not use kerosene on the blade.) The several portions are then to be pressed in a can of not less than 1 quart capacity, using a quantity of material which will nearly fill the can, which is then to be tightly covered. If cans are not available and some other type of container is used, it must be entirely free from paper or any other substance to which the bituminous material adheres readily.

Check field samples are recommended on plant-inspected material.

Field sampling.—For barrel shipments, see plant barrel sampling.

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[14] Intervals of 500 feet are suggested.

Sampling fluid products.—When a fluid material is shipped in tank cars, and the sample is to be taken directly from the tank car to represent an average of the entire tank-car contents, the following method is suggested:

A tin can, with a tight-fitting removable cover and wire handle, is secured, and a number of holes one-eighth of an inch in diameter are punched in the cover. This bucket is then weighted in any convenient way and lowered slowly by means of a cord attached to the handle through the entire depth of the tank car, so that the can will be filled with material from all depths of the car. This can is then emptied into another can of at least 1 quart capacity having a screw top or other equally tight cap or cover. A sample is more representative when the tank car has been agitated before the sample is taken.

Where individual samples are desired to check the uniformity of material throughout a tank car, it is suggested that thief samples be taken from top and middle and a third sample be taken from the outlet valve through which a sufficient amount of bituminous material has been allowed to flow in order to clean the valve properly.

Semisolid products.—Barrel shipments are to be sampled as in plant sampling.

Tank-car shipments are to be sampled through the dome by the use of a clean hot shovel.

Bituminous aggregates.[15]—It is suggested that a 5-pound sample be submitted when the material is sampled before being placed in the pavement.

Samples of pavements should be at least 1 square foot in area.

The material should be carefully boxed in order that it may remain intact during transit.

59. SAMPLING PORTLAND CEMENT.

See test No. 17.

60. SAMPLING PAVING BRICK.

See test No. 18.

61. SAMPLING METAL CULVERTS.

Owing to lack of uniformity of spelter coating on culvert sheets, it is recommended that as many samples as possible be taken from different culverts, each sample to be about 3 inches square.

The samples should be straightened preferably in a press or vise—*under no circumstances should they be hammered.*

62. SAMPLING OF PAINT AND PAINT MATERIALS.

Where a shipment of such material consists of a number of separate packages a sample should be taken from a sufficient number of such packages to give a representative composite sample. The contents of the containers should be stirred to homogeneous consistency before sampling.

In case of mixed paints, oils, and thinners the sample should be at least a pint. Preferably the sample should be placed in an air-tight friction top can. In the case of pastes and dried pigments the sample should be approximately 1 pound.

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[15] The term "bituminous aggregate" is defined as follows: The mineral or other aggregate, together with the bitumen which is used as the cementing medium.

MISCELLANEOUS MATTER.

63. LIST OF APPARATUS FOR CONDUCTING TESTS ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION.[16]

Analytical balance with necessary weights.
Rough balance.
Pycnometer—Hubbard-Carmick type.
Hydrometers and jar.
Penetrometer.
Constant temperature oven.
Open cup flash tester.
Ring and ball apparatus.
Ductility machine.
Erlenmeyer flasks.
Porcelain gooch crucibles and asbestos.
Aluminum float with three brass collars.
Engler flasks (250 c. c. distillation flasks of special dimension).
Condenser tubes.
25 c. c. graduates.
Sprengel tubes.
Copper still, with steel clamps, inside dimensions 6 by 3½ inches.
Ring burner to fit copper still.
Engler viscosimeter with standard thermometer.
Extractor for bituminous mixes.
Platinum crucible, cover and triangle.
Vacuum pump.
Spatula knives.
Stop watch.
Burners, Meker and Tirrill.
Rubber tubing.
Stirring rods.
Tripods.
Thermometers.
Triangles.
Wire gauze.
Hot plate.
Water still.
Desiccator.
3-ounce tin cans, deep pattern, Gill type, American Can Co.
2-ounce tin cans.

64. LIST OF APPARATUS FOR PHYSICAL TESTING OF NONBITUMINOUS ROAD MATERIALS.[17]

1 Deval abrasion machine with four cylinders.
1 impact machine for toughness test (optional).
1 diamond-core drill, with suitable drill press (optional).
1 diamond saw (optional).
1 grinding lap (optional).
5 pounds No. 120 carborundum.
1 forcing press for breaking samples for Deval test (optional).
1 scale, capacity 5 kilograms and sensitive to 0.5 gram.
1 scale, capacity 1,000 grams and sensitive to 0.1 gram.
1 large drying oven.
1 10-inch desiccator, with calcium chloride.
1 millimeter scale.
1 100 c. c. graduate.
1 100 c. c. beaker.
1 16-inch sieve, reinforced, with square openings $\frac{1}{16}$ inch in size.
1 50-pound anvil.
1 10-pound sledge.
1 3-pound double-face stone hammer.
1 1½-pound single-face stone hammer.
1 6-inch scoop.
1 cement-testing machine.
1 200,000-pound testing machine, Universal type (optional).
6 3-gang cement molds.
1 set of Gilmore needles } one optional.
1 Vicat needle }
1 complete set of standard screens and sieves.
1 platform scale.
1 mixing pan for concrete, 3 by 4 feet.
1 large trowel.
1 small trowel.
1 sieve agitator.
1 cement-mixing table with nonabsorbent top.
1 nonabsorbent closet for storage of briquettes.
1 apparatus for accelerated soundness test.
6 pieces plate glass, 4 by 12 inches.
6 pieces plate glass, 4 by 4 inches.
1 immersion tank for storage of briquettes.
1 pair seamless rubber gloves.
12 6 by 12 inch cylindrical molds with metal base plates.
1 truncated cone for slump test, 4 by 12 by 8 inches.
1 specific gravity vessel (Bull. 555, U. S. Dept. of Agric., fig. 1).
1 Le Chatelier specific gravity flask.
100-pound bag standard Ottawa sand.
1 ¼-cubic foot cylindrical measure.
1 cubic foot measure.
1 tempering tank for mixing water.
1 puddling bar ⅝ by 21 inches.

[16] This list includes those items of equipment that would be used ordinarily. A number of additional pieces of apparatus might be required for occasional tests.

[17] This list includes items of equipment that will be used continuously and also certain items of equipment which will be used only occasionally, and these latter are indicated as "optional."

65. THE MANUFACTURE AND USE OF LABORATORY DIAMOND CORE DRILLS.

Black carbons or diamonds used for laboratory drills should range from $\frac{1}{16}$ to $\frac{5}{32}$ inch in size, and should be dense and regular in shape. Diamonds suitable for the work will weigh in the neighborhood of 0.1 carat each and from six to eight diamonds are required for a 1-inch drill. They may be obtained from any of the diamond importers.

The diamond drill consists of a bronze crown soldered to the end of a seamless steel tube about 4½ inches long and 1⅛ inches outside diameter and carrying six diamonds, each about $\frac{3}{32}$ inch in diameter. The other end of the steel tube carries a No. 2 Morse taper hollow drill shank through which water is admitted to the inside of the drill. The drill crown proper is made of Tobin bronze, 1-inch internal diameter, $1\frac{7}{32}$-inch external diameter, ¼ inch high, with a recess $\frac{3}{32}$ inch in depth by 1⅛ inches in diameter in which the steel tube is soldered. Figure 3 gives a detailed view of the drill crown showing the various dimensions. In figure 36 are shown the various pieces of apparatus used in the operation of setting the diamonds in the drill crown. *A* is a piece of cold-drawn steel 1¼ by ½ by 6 inches with a yoke *C* and thumbscrew and is used to

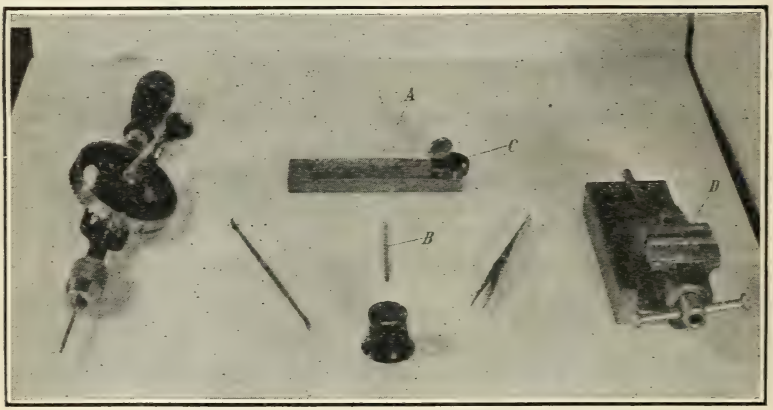

FIG. 36.—Apparatus used in manufacture of diamond drill.

hold the drill crowns. After mounting a crown in the clamp as shown, six holes are drilled in the face of the crown at equal distances apart, three of the holes almost breaking through the outside of the face of the ring and three almost breaking through the inside of the face. The holes should be slightly smaller than the diamonds which are to be used, and each should be slightly nicked on the thin edge with a fine file. A diamond is now placed in one of the holes, gently tapped with a piece of brass so as to hold it in place, after which the crown is placed in a small jeweler's vice "*D*" having jaws of soft steel or brass and with which the diamond is forced into the hole. Should the diamond not stand the pressure and crumble, it is not fit for drilling and should be used for other purposes. It should be possible to force any diamond good enough for drilling purposes into a hole in the above manner. Flat drills *B*, made of ⅛-inch drill rod, turned to about ½ inch long and of a size slightly smaller than the diamonds, are used for drilling the holes. It has been found that the flat drills are better than twist drills for they are stiffer and do away with a center punch. After the diamonds are all set, the drill is soft soldered to the end of the steel tube and is then ready for use.

Any drill press equipped with a hollow spindle and with the table so arranged that the water carrying the rock cuttings may be properly collected and carried away is satisfactory for use in rock drilling. A drill press carrying a No. 2 Morse taper is large enough. The speed of the drill should be in the neighborhood of 300 revolutions per minute.

Great care should be exercised when first using a diamond drill. A block of very soft limestone or sandstone should be selected and a number of cores cut from this stone until it is found that the drill is working properly, after which it may be used

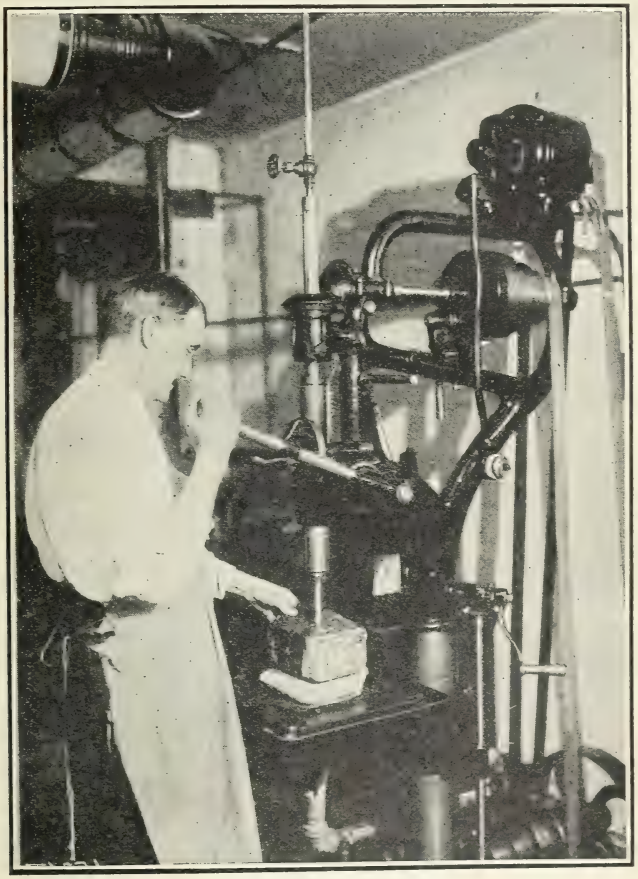

FIG. 37.—Diamond drill in use.

on harder rock. The sample should be bedded on a bag filled with sand as shown in figure 37, or in the case of very small pieces, it may be necessary to mount the samples in plaster of Paris before drilling. Plenty of water should be used on the inside of the drill so as to keep the space under the crown entirely free from rock cuttings, which, especially in the case of soft rock, have a tendency to "gum up" the drill. After one or two cores have been drilled, their diameter should be measured, and if it is found that the drill is cutting cores more than 25 mm. or less than 24 mm. in diameter, one or two of the diamonds must be reset. If the drill crown is turned to the dimen-

sions shown, however, and the diamonds set as indicated, the cores should come out very close to 25 mm. in diameter. The pressure should be applied always by hand and never automatically on account of the tendency of carbons to shatter if subjected to any appreciable impact. When drilling stone by hand, the pressure on the drill may be regulated in accordance with the character of the material being drilled. This is, of course, not the case if an automatic feed is used. A much greater pressure may be used when drilling fine-grained, homogeneous materials, such as trap, even if the rock is very hard, than in the case of coarse-grained, non-homogeneous materials or stone in which minerals of greater hardness than the mass of the rock are embedded. With a properly constructed drill, it should be possible to cut a core 4 inches in length from rock of medium hardness in about 10 minutes. Properly constructed drills will cut from 20 to 50 feet of rock, depending, of course, on the average hardness of the stone being used.

66. FORMS FOR RECORDING AND REPORTING RESULTS.

(Name of laboratory.)

ROCK TESTS.

Serial No...... *From*..... (County.) (State.) *Name*.....

SPECIFIC GRAVITY—ABSORPTION.

	(1)	(2)
Wt. in air		
Wt. in water		
Loss in wt.		
Wt. 96 hrs.		
Gain 96 hrs.		
Sp. gr.		
Absorption		

Sp. gr.....; Wt. cu. ft.....

Abs. lbs. cu. ft.....

Tested by....., Compt....., Chk.....

CEMENTING VALUE.

1..... 2..... 3..... 4..... 5.....

Avg. No. blows.....

Tested by....., Compt....., Chk.....

ABRASION.

No. pieces.....

Initial wt.....

Final wt.....

Under $\frac{1}{16}$ in.....

Per cent wear....., Fr. coef.....

Tested by....., Compt....., Chk...

COMPRESSION.

	(1)	(2)
Diam. cyl.		
Sec. area		
Total load		
Unit load		

Cr. str. lbs. per sq. in.....

Tested by....., Compt....., Chk....

HARDNESS.

	(1)	(2)
Initial wt.		
Final wt.		
Loss 1,000 rev.		
Loss.....rev.		

Hard. coef.....

Avg. hard. coef.....

Tested by....., Compt....., Chk.....

TOUGHNESS.

	(1)	(2)
Ht. blow cms.		

Av. toughness.....

Tested by....., Compt....., Chk.....

Remarks:..... *Reported*.....

(Name of laboratory.)

SAND AND GRAVEL TESTS.

Serial No. ..... *From* ..... (Town) ..... (County) ..... (State) ..... *Name* .....

MECHANICAL ANALYSIS.

Pass.—Ret.	Wt.	%	Pass.—Ret.	Wt.	%
Over 3 in.			¼ in.—No. 10		
3 in.—2½ in.			No. 10—No. 20		
2½ in.—2 in.			No. 20—No. 30		
2 in.—1½ in.			No. 30—No. 40		
1½ in.—1 in.			No. 40—No. 50		
1 in.—¾ in.			No. 50—No. 80		
¾ in.—½ in.			No. 80—No. 100		
½ in.—¼ in.			No. 100—No. 200		
Over ¼ in.			Under No. 200		
Original wt.					

Tested by ..... Compt ..... Chk .....

UNDER NO. 200 MESH BY WASHING.

Orig. wt .....; final wt .....; loss .....

Per cent loss .....

Tested by ..... Compt ..... Chk .....

TENSION TESTS.

Sample Sand.		Ottawa Sand.	
7-day.	28-day.	7-day.	28-day.
Ave.			

Strength ratio, 7 days ..... %; 28 days ..... %

Water used, sample ..... Ottawa .....

Made by ..... Date .....

Tested by ..... at 7 days; by ..... at 28 days.

CEMENTING VALUE.

1....., 2....., 3....., 4....., 5..... Ave.....

Tested by ..... Compt ..... Chk .....

Remarks: .....

Received .....

Reported, 7-day .....; 28-day .....

(Name of laboratory.)

CEMENT TESTS

Serial No...... *Marked*..... *Received*..... *Name*.....

Sent by..... *From*..... (County.) (State.)

At request of..... *Condition*..... *Weight*.....

SPECIFIC GRAVITY (Le Chatelier):

1. ..... Made by..... Date.....

2. .....(Ignited.) Made by..... Date.....

FINENESS: Made by..... Date.....

Passing No. 100 sieve..... %

Passing No. 200 sieve..... %

TIME OF SETTING: Made by..... Date.....

Initial.....hr. .....min.

Final.....hr. .....min.

SOUNDNESS:

Pat steamed 5 hrs. .....

.....

Pat in air 28 days.....

.....

Pat in water 28 days.....

.....

NORMAL CONSISTENCY:

.....

TENSILE STRENGTH:

Neat Made by..... Date.....

24 hour.	7 day.	28 day.		
Ave.				

1 : 3 Made by..... Date.....

Ave.				

.....SO_3.....MgO.....

REMARKS:.....

29465°—21—Bull. 949——6

(Name of laboratory.)

BRICK TESTS

Serial No...... *Used*..... *Brand*.....
(Town.) (County.) (State.)

DIMENSIONS

Length, ins.	Breadth, ins.	Depth, ins.

Tested by..... Ck.....

ABSORPTION.

RATTLER TEST

CHARGE

	No.	Wt. Lbs.	
Large spheres			
Small spheres			
Total charge			

RUNNING DATA

Initial wt.....	.....lbs.	Revolutions	Time
Final wt.....	.....lbs.	Begin.....	.....
Loss.....	.....lbs.	End.....	.....

Per cent Loss.....

Tested by....., Compt....., Ck.....

No. of Tests since last inspection.....

Remarks.....

.....

Received..... *Reported*.....

(Name and location of laboratory.)

REPORT ON SAMPLE OF ROCK OR SLAG.

Laboratory No. .....

....., 192....
(Date reported.)

Name.....

Identification marks.....

Submitted by..... Title..... Address.....

Sampled....., 192... Received....., 192..

Sampled from.....

Quantity represented.....

Source of material.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

Specific gravity.....

Weight per cubic foot, in pounds.....

Water absorbed per cubic foot, ...pounds .....per cent

Per cent of wear..... .....

French coefficient of wear..... .....

Hardness..... .....

Toughness..... .....

Remarks:

Respectfully submitted.

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF GRAVEL OR SAND.

Laboratory No. .....

....., 192...
(Date reported.)

Name.....

Identification marks.....

Submitted by..... Title..... Address.....

Sampled....., 192... Received....., 192...

Sampled from.....

Quantity represented.....

Source of material.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

SAND. Mechanical analysis.		GRAVEL. Mechanical analysis.	
Fraction.	Per cent.	Fraction.	Per cent.
Retained ¼-inch screen		Retained 3-inch screen	
Passing ¼-inch retained 10 mesh		Passing 3-inch retained 2½ inch	
Passing 10 mesh retained 20 mesh		Passing 2½-inch retained 2 inch	
Passing 20 mesh retained 30 mesh		Passing 2-inch retained 1½ inch	
Passing 30 mesh retained 40 mesh		Passing 1½-inch retained 1 inch	
Passing 40 mesh retained 50 mesh		Passing 1-inch retained ¾ inch	
Passing 50 mesh retained 60 mesh		Passing ¾-inch retained ½ inch	
Passing 60 mesh retained 80 mesh		Passing ½-inch retained ¼ inch	
Passing 80 mesh retained 100 mesh		Passing ¼-inch screen	
Passing 100 mesh retained 200 mesh			
Passing 200 mesh			
Total		Total	
Silt in sand		Per cent of wear	

Tensile strength (cement-sand briquettes, 1:3).	Sample sand.			Standard Ottawa sand.		
	3-day.	7-day.	28-day.	3-day.	7-day.	28-day.
1						
2						
3						
4						
5						
Average						
Ratio						

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF SEMI-GRAVEL, TOP SOIL, OR SAND CLAY

Laboratory No. ...., 192..
(Date reported.)

Name.....

Identification marks .....

Submitted by..... Title..... Address.....

Sampled....., 192.. Received....., 192..

Sampled from .....

Quantity represented .....

Source of material.....

Location used or to be used.....

Examined for.....

TEST RESULTS.

Analysis of material passing 10-mesh sieve.

	Per cent.	Per cent.	Per cent.	Character.
Sand retained, 20 mesh.....				
Passing 20, retained 60 mesh.....				
Passing 60, retained 100 mesh.....				
Passing 100, retained 200 mesh.....				
Total sand.....				
Silt.....				
Clay.....				
Total.....				
Total sand retained on 60 mesh...				

Coarse material, ... per cent. Quality, ...

Mica, ...

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF PORTLAND CEMENT.

Laboratory No..... ....., 192...
(Date reported.)

Brand.....
Identification marks.....
Submitted by..... Title..... Address.....
Sampled....., 192... Received....., 192...
Sampled from.....
Quantity represented.....
Manufactured by.....
Location used or to be used.....
Examined for.....

TEST RESULTS.

Chemical tests:
- Loss on ignition, per cent.....
- Insoluble residue, per cent.....
- Sulphuric anhydride (SO_3), per cent.....
- Magnesia (MgO), per cent.....

Physical tests:
- Specific gravity.....
- Per cent retained on 200-mesh sieve.....
- Steam test.....

	Gillmore needle.		Vicat needle.
Initial set	.....	or	.....
Final set	.....	or	.....

Tensile strength (1 : 3 Ottawa sand):

7 days.	28 days.
.....	.....
.....	.....
.....	.....
Average:	Average: .....

Remarks:

Respectfully submitted.

.....
(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF VITRIFIED PAVING BRICK.

(Date reported.)

Laboratory No..... ....., 192..
Trade name.....
Identification marks.....
Submitted by..... Title..... Address.....
Sampled....., 192.. Received....., 192..
Sampled from.....
Quantity represented.....
Manufactured by.....
Location used or to be used.....
Examined for.....

TEST RESULTS.

General data.

Average dimensions, length..... Width..... Depth.....
Drying treatment.....

Standardization data.

	Weight of charge (after standardization).	Number of fresh stave liners.	Repairs affecting barrel.
10 large spheres.....			
small spheres.....			
Total.....			

Number of charges tested since last inspection, ...

Running data.

	Time readings.			Revolution counter readings.	Running notes, stops, etc.
	Hours.	*Minutes.*	*Seconds.*		
Beginning of test.....					
Final reading.....					

Initial weight of 10 bricks..... ....
Final weight of 10 bricks..... ....
Loss of weight..... ....
Loss of weight, per cent..... ....
Number of bricks broken in test. ....

Maximum variation in per cent loss.

Remarks:

Respectfully submitted,

.....

(Title).....

(Name and location of laboratory.)

REPORT ON SAMPLE OF (TARS OR TAR PRODUCTS).

Laboratory No. ...., 192...
Identification marks: .....
Submitted by .....
Sampled ....., 192... Received ....., 192..
Sampled from .....
Quantity represented: .....
Trade name: .....
Manufactured by ..... at .....
Location used or to be used: .....
Examined for .....

TEST RESULTS.

GENERAL CHARACTERISTICS:

Water.....
Specific gravity, 25° C./25° C. .....
Specific viscosity, Engler, ... °C. .....
Float test, ... °C. [seconds] .....; ..... °C. [seconds] .....
Melting point .... [°C.] .....
Total bitumen (soluble in carbon disulphide) [per cent].....
Free carbon (organic matter insoluble) [per cent].....
Inorganic matter insoluble [per cent].....
Distillation

FRACTIONS.	CHARACTER.	% BY VOL.	% BY WT.
..... –170° C.	.....		
170° C.–235° C.	.....		
235° C.–270° C.	.....		
270° C.–300° C.	.....		
Residue	.....		

Specific gravity of distillate, 25° C./25° C. .....
Melting point of residue ..... [°C.] .....
Remarks:

Respectfully submitted,

.....
(Title.)

(Name and location of laboratory.)

REPORT ON SAMPLE OF (PETROLEUM OR ASPHALT PRODUCTS).

Laboratory No. ...., 192...
Identification marks: .....
Submitted by .....
Sampled ....., 192... Received ....., 192...
Sampled from .....
Quantity represented: .....
Trade name: .....
Manufactured by ..... at .....
Location used or to be used: .....
Examined for .....

TEST RESULTS.

GENERAL CHARACTERISTICS:

Specific gravity, 25° C./25° C. .....
Flash point .... [°C.] .....
Specific viscosity, Engler, ... °C. .....
Float test, ... °C. [seconds] .....; °C. [seconds] .....
Penetration, 0° C. 200 grams, 60 seconds .....
Penetration, 25° C. 100 grams, 5 seconds .....
Penetration, 46.1° C. 50 grams, 5 seconds .....
Melting point .... [°C.] .....
Ductility, ... °C. [cm.] .....; ..... °C. [cm.] .....
Loss, 163° C., 5 hours [per cent] .....
Characteristics of residue.
Consistency of residue { Penetration, 25° C. 100 grams, 5 seconds .....
Float test, ... °C. [seconds] .....; .... °C. [seconds] ...
Total bitumen (soluble in carbon disulphide) [per cent] .....
Organic matter insoluble [per cent] .....
Inorganic matter insoluble [per cent] .....
Per cent of total bitumen insoluble in 86° B. naphtha .....
Fixed carbon [per cent] .....
Remarks:

Respectfully submitted,

.....
(Title.)

(Name and location of laboratory.)

REPORT ON SAMPLE OF (MISCELLANEOUS MATERIALS).

Laboratory No. ...., 192...
Name .....
Identification marks .....
Submitted by .....
Sampled ....., 192... Received ....., 192...
Sampled from .....
Quantity represented .....
Source of material .....
Location used or to be used .....
Examined for .....

TEST RESULTS.

Respectfully submitted,

.....
(Title.)

(Name and location of laboratory.)

Laboratory No. .....

REPORT ON SAMPLE OF (MISCELLANEOUS MATERIALS).

Identification marks: .....

Submitted by .....

Sampled ....., 192 , from ..... Quantity represented: .....

Trade name: .....

Source of material: .....

Location used or to be used: .....

Examined for .....

General characteristics: .....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Received ....., 192 Acknowledged ....., 192 Examined ....., 192 Reported ....., 192 Analyst .....

(Name and location of laboratory.)

Laboratory No. .....

REPORT ON SAMPLE OF (TARS AND TAR PRODUCTS).

Identification marks: .....

Submitted by .....

Sampled ....., 192 , from ..... Quantity represented: .....

Trade name: .....

Manufactured by ..... at .....

Location used or to be used: .....

Examined for .....

General characteristics: ..... Distillation..... Character .....

	Per cent by vol.	Per cent by wt.
170° C.		
170°–235° C.		
235°–270° C.		
270°–300° C.		
Residue		
.....		

Specific gravity 25°/25° C. .....

Specific viscosity, Engler, ...° C. .....

Float Test, ...° C. (sec.) .....; .....° C. (sec.).....

Melting point (° C.).....

Total bitumen (soluble in CS_2) (per cent).....

Free carbon (organic matter insoluble) (per cent).....

Inorganic matter insoluble (per cent)..... Specific gravity of distillate 25°/25° C. .....

Water (per cent) ..... Melting point of residue (°C.) .....

.....

.....

Received....., 192 Acknowledged....., 192 Examined....., 192 Reported....., 192 Analyst.....

(Name and location of laboratory.)

REPORT ON SAMPLE OF (PETROLEUM OR ASPHALT PRODUCTS). *Laboratory No.* .....

Identification marks: .....

Submitted by .....

Sampled ....., 192 , from ..... Quantity represented: .....

Trade name: .....

Manufactured by ..... at .....

Location used or to be used: .....

Examined for .....

General characteristics:	Ductility ....° C. (cm.) .....
Specific gravity 25°/25° C.	Loss, 163° C., 5 hours (per cent) .....
Flash point (° C.)	Characteristics of residue: .....
Burning point (° C.)	Penetration of residue 25° C., 100 grams, 5 seconds .....
Specific viscosity, Engler, ...° C.	Float test of residue ....° C. (sec.) .....; ° C. (sec.) .....
Float test, ...° C. (sec.) .....; .....° C. (sec.)	Total bitumen (soluble in CS_2) (per cent) .....
Penetration, 0° C., 200 grams, 60 seconds	Organic matter insoluble (per cent) .....
Penetration, 25° C., 100 grams, 5 seconds	Inorganic matter insoluble (per cent) .....
Penetration, 46.1° C., 50 grams. 5 seconds	Per cent of total bitumen insoluble in 86° B. naphtha .....
Melting point (° C.)	Fixed carbon (per cent) .....

.....

Received ....., 192 Acknowledged ..... 192 Examined ..... 192 Reported ..... ., 192 Analyst .....

67. COMPARISON OF DEGREES BAUMÉ AND SPECIFIC GRAVITY.

(Liquids lighter than water.)

(1) $\text{Sp. gr.} = \frac{140}{130 + {}^\circ\text{B.}}$ at 15.5° C. (2) $^\circ\text{B.} = \frac{140}{\text{Sp. gr.}} - 130$ at 15.5° C.

°B.	Sp. gr.	°B.	Sp. gr.	°B.	Sp. gr.	°B.	Sp. gr.
10	1.0000	31	0.8695	52	0.7692	73	0.6896
11	.9929	32	.8641	53	.7650	74	.6863
12	.9859	33	.8588	54	.7609	75	.6829
13	.9790	34	.8536	55	.7567	76	.6796
14	.9722	35	.8484	56	.7526	77	.6763
15	.9655	36	.8433	57	.7486	78	.6731
16	.9589	37	.8383	58	.7446	79	.6698
17	.9523	38	.8333	59	.7407	80	.6666
18	.9459	39	.8284	60	.7368	81	.6635
19	.9395	40	.8235	61	.7330	82	.6604
20	.9333	41	.8187	62	.7292	83	.6573
21	.9271	42	.8139	63	.7254	84	.6542
22	.9210	43	.8092	64	.7216	85	.6511
23	.9150	44	.8045	65	.7179	86	.6482
24	.9090	45	.8000	66	.7143	87	.6452
25	.9032	46	.7954	67	.7167	88	.6422
26	.8974	47	.7909	68	.7071	89	.6393
27	.8917	48	.7865	69	.7035	90	.6363
28	.8860	49	.7821	70	.7000		
29	.8805	50	.7777	71	.6965		
30	.8750	51	.7734	72	.6931		

68. COMPARISON OF CENTIGRADE AND FAHRENHEIT DEGREES.

(1) $^\circ\text{F.} = \frac{9}{5}{}^\circ\text{C.} + 32.$ (2) $^\circ\text{C.} = \frac{5(^\circ\text{F.} - 32).}{9}$

C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.
0	32.0	38	100.4	76	168.8	114	237.2	152	305.6	190	374.0
1	33.8	39	102 2	77	170.6	115	239.0	153	307.4	191	375.8
2	35.6	40	104.0	78	172.4	116	240.8	154	309.2	192	377.6
3	37.4	41	105.8	79	174.2	117	242.6	155	311.0	193	379.4
4	39.2	42	107.6	80	176.0	118	244.4	156	312.8	194	381.2
5	41.0	43	109.4	81	177.8	119	246.2	157	314.6	195	383.0
6	42.8	44	111.2	82	179.6	120	248.0	158	316.4	196	384.8
7	44.6	45	113.0	83	181.4	121	249.8	159	318.2	197	386.6
8	46.4	46	114.8	84	183.2	122	251.6	160	320.0	198	388.4
9	48.2	47	116.6	85	185.0	123	253.4	161	321.8	199	390.2
10	50.0	48	118.4	86	186.8	124	255.2	162	323.6	200	392.0
11	51.8	49	120.2	87	188.6	125	257.0	163	325.4	201	393.8
12	53.6	50	122.0	88	190.4	126	258.8	164	327.2	202	395.6
13	55.4	51	123.8	89	192.2	127	260.6	165	329.0	203	397.4
14	57.2	52	125.6	90	194.0	128	262.4	166	330.8	204	399.2
15	59.0	53	127.5	91	195.8	129	264.2	167	332.6	205	401.0
16	60.8	54	129.2	92	197.6	130	266.0	168	334.4	206	402.8
17	62.6	55	131.0	93	199.4	131	267.8	169	336.2	207	404.6
18	64.4	56	132.8	94	201.2	132	269.6	170	338.0	208	406.4
19	66.2	57	134.6	95	203.0	133	271.4	171	339.8	209	408.2
20	68.0	58	136.4	96	204.8	134	273.2	172	341.6	210	410.0
21	69.8	59	138.2	97	206.6	135	275.0	173	343.4	220	428.0
22	71.6	60	140.0	98	208.4	136	276.8	174	345.2	230	446.0
23	73.4	61	141.8	99	210.2	137	278,6	175	347.0	240	464.0
24	75.2	62	143.6	100	212.0	138	280.4	176	348.8	250	482.0
25	77.0	63	145.4	101	213.8	139	282.2	177	350.6	260	500.0
26	78.8	64	147.2	102	215.6	140	284.0	178	352.4	270	518.0
27	80.6	65	149.0	103	217.4	141	285.8	179	354.2	280	536.0
28	82.4	66	150.8	104	219.2	142	287.6	180	356.0	290	554.0
29	84.2	67	152.6	105	221.0	143	289.4	181	357.8	300	572.0
30	86.0	68	154.4	106	222.8	144	291.2	182	359.6	350	662.0
31	87.8	69	156.2	107	224.6	145	293.0	183	361.4	400	752.0
32	89.6	70	158.0	108	226.4	146	294.8	184	363.2	450	842.0
33	91.4	71	159.8	109	228.2	147	296.6	185	365.0	500	932.0
34	93.2	72	161.6	110	230.0	148	298.4	186	366.8	550	1,022.0
35	95.0	73	163.4	111	231.8	149	300.2	187	368.6	600	1,112.0
36	96.8	74	165.2	112	233.6	150	302.0	188	370.4	650	1,202.0
37	98.6	75	167.0	113	235.4	151	303.8	189	372.2	700	1,292.0

69. METRIC CONVERSION TABLES.

Length.		Capacity.		Mass.	
Inches.	Millimeters.	United States liquid ounces.	Cubic centimeters.	Avoirdupois ounces.	Grams.
1/32=0.0312	0.7938	1	29.574	1	28.3495
1/16= .0625	1.5875	2	59.147	2	56.6991
1/8= .1250	3.1750	3	88.721	3	85.0486
1/4= .2500	6.3500	4	118.295	4	113.3981
1/2= .5000	12.7000	5	147.869	5	141.7476
1	25.4001	6	177.442	6	170.0972
2	50.8001	7	207.016	7	198.4467
3	76.2002	8	236.590	8	226.7962
4	101.6002	9	266.163	9	255.1457
5	127.0003	16=1 pt	473.18	16=1 lb	453.59
6	152.4003	32=1 qt	946.36	0.3527	10
7	177.8004	128=1 gal.	3,785.43	.7055	20
8	203.2004	0.3381	10	1.0582	30
9	228.6005	.6763	20	1.4110	40
		1.0144	30	1.7637	50
		1.3526	40	2.1164	60
		1.6907	50	2.4692	70
		2.0288	60	2.8219	80
		2.3670	70	3.1747	90
		2.7051	80	3.5270	100
		3.0432	90	35.27	1,000=1 kilogram.
		3.3810	100		
		33.81	1,000=1 liter.		

Centimeters.	
0.3937	1=10 mm.
.7874	2
1.1811	3
1.5748	4
1.9685	5
2.3622	6
2.7559	7
3.1496	8
3.5433	9

70. REFERENCES TO TESTS FOR PAINT AND PAINT MATERIALS, SEWER PIPE, DRAIN TILE, AND METALS.

Determination of Per cent Pigment in Paints (See Page 68).

Standard Methods for Routine Analysis of White Pigments.
(Refer to A. S. T. M. Standard Method, Serial Designation: D34–17.)

Standard Methods for Routine Analysis of Dry Red Lead.
(Refer to A. S. T. M. Standard Method, Serial Designation: D49–18.)

Standard Methods for Routine Analysis of Yellow, Orange, Red, and Brown Pigments containing Iron and Manganese.
(Refer to Standard Method, Serial Designation: D50–18.)

Standard Specifications for Turpentine.
(Refer to A. S. T. M. Standard, Serial Designation: D13–15.)

Standard Tests for Paint Thinners other than Turpentine.
(Refer to A. S. T. M. Standard Method, Serial Designation D28–17.)

Standard Specifications for Purity of Boiled Linseed Oil from North American Seed.
(Refer to A. S. T. M. Standard, Serial Designation: D11–15.)

Standard Specifications for Purity of Raw Linseed Oil from North American Seed.
(Refer to A. S. T. M. Standard, Serial Designation: D1–15.)

Tentative Specifications for Cement Concrete Sewer Pipe.
(Refer to A. S. T. M. Tentative Standard, Serial Designation: C14–19T.)

Standard Specifications for Drain Tile.
(Refer to A. S. T. M. Standard, Serial Designation: C4–16.)

Tentative Specifications for Clay Sewer Pipe.
(Refer to A. S. T. M. Tentative Standard, Serial Designation: C13–18T.)

Tests for Spelter Coatings on Culvert Metals.
(See page 68.)

Standard Specifications for Structural Steel for Bridges.
(Refer to A. S. T. M. Standard Method, Serial Designation: A7–16.)

Standard Methods for Chemical Analysis of Plain Carbon Steel.
(Refer to A. S. T. M. Standard Method, Serial Designation: A33–14.)

Standard Specifications for Billet Steel Concrete Reinforcement Bars.
(Refer to A. S. T. M. Standard Method, Serial Designation: A15–14.)

INDEX.

TENTATIVE TESTS.

RECOMMENDED STANDARD METHODS FOR SAMPLING.

MISCELLANEOUS.

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